Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

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HYDRO-ELECTRIC

POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

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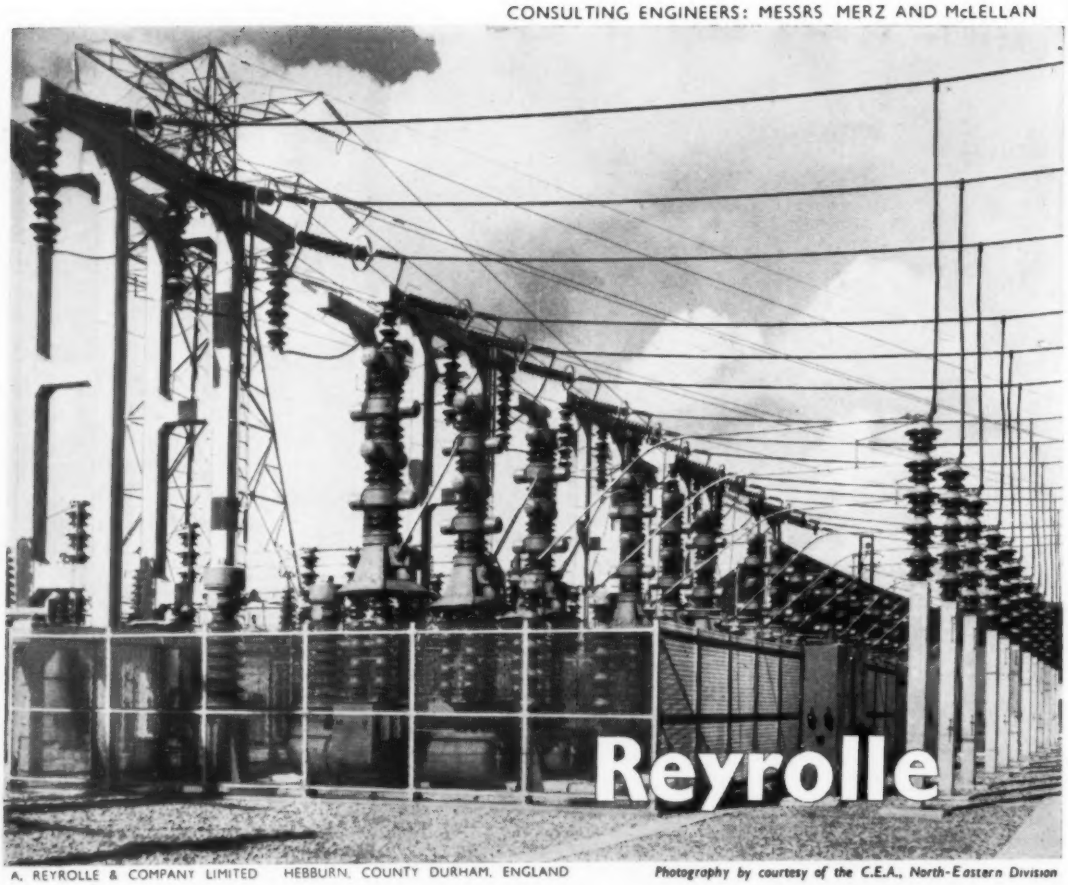

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Annually 35 shillings by post. Single Copies 2s. 6d.

Volume 9 Number 4

CONTENTS FOR APRIL, 1957

Editorial: Measuring Equipment - - - 119

Editorial Notes - - - - - 120

Enlarged Eildon Irrigation and Hydro-Electric Scheme 123

Chippawa-Grass Island Pool Control Structure - 129
By J. L. Soare, B.Sc., C.E., P.Eng.

Vibrations in Hydro-Electric Installations—I - - 132
By Serge Leliavsky, Ph.D., M.I.C.E., M.Am.Soc.C.E.

Hells Canyon - - - - - 138
By Ian B. Mackintosh, M.A., A.M.I.C.E., A.M.A.S.C.E.

Progress on St. Lawrence Seaway Scheme - - 144
By H. G. Cochrane, M.E.I.C.

The Durance Project—I - - - - 146
By Peter O. Wolf, B.Sc.(Eng.), A.M.I.C.E., A.M.I.W.E.

Book Reviews - - - - - 150

Short Articles: The Stornorrfors Turbines—English Electric 65° Rise Motors—Contractors' Submersible Drainage Pump - - - - - 152

Abstracts from the World Technical Press - - 156

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PUBLISHED BY TOTHILL PRESS LIMITED

33 Tothill Street, Westminster, London, S.W.1

Telegrams: Trazette, Parl, London. Telephone: Whitehall 9233 (20 lines)

MANCHESTER: Century Insurance Building, St. Peter's Square. Telephone: Central 3101

BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466

NEWCASTLE-ON-TYNE: 21 Mosley Street. Telephone: 22239

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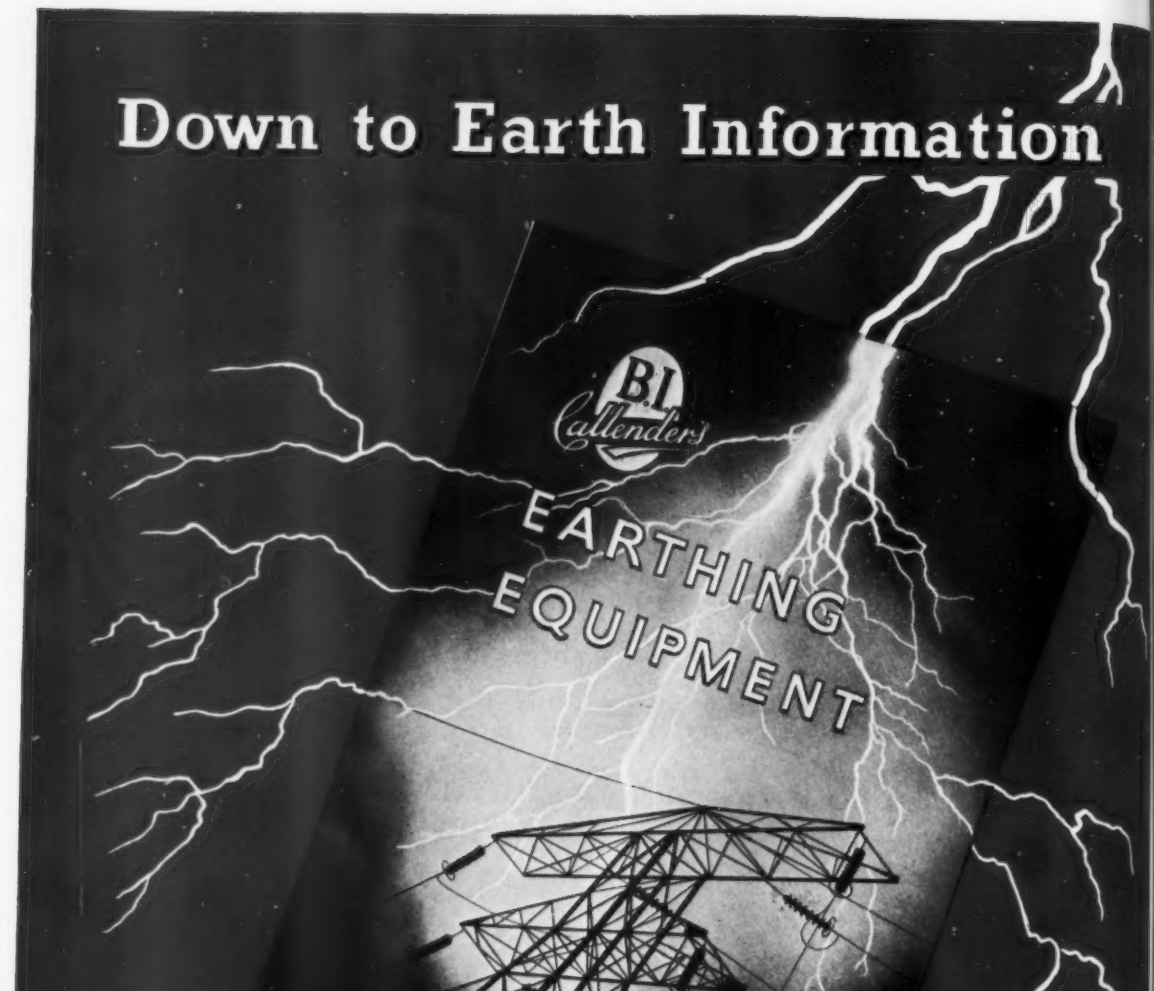

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Measuring Equipment

THE increasing cost of all civil-engineering work, together with the need to exploit hydro-electric resources to the utmost wherever they may be available, has meant on the one hand that engineers are forced to take into consideration constructional methods which, perhaps, some years ago they might not have felt to have formed the best available solution, while on the other hand it has been necessary to consider utilising sites which are not the most suitable from the civil-engineering point of view.

Perhaps the worst case, combining these two difficulties, is that of building a rolled-earth dam on a compressible foundation, and it is interesting how nowadays the foresight of engineers faced with such problems (generally on a much more limited scale) some twenty or thirty years ago is at length being rewarded, for in many cases, they installed elaborate means for detecting and recording every kind of movement and settlement.

In all matters regarding the movement of such structures as dams time is the only factor which furnishes any data of value. Settlement takes place slowly, and so it is not until after five or ten years' operational experience has been gained that the full harvest of this early work with measuring equipment can be fully reaped. French and Italian engineers and the staff of the Tennessee Valley Authority have been particularly forward-looking in this matter.

We recall a paper by C. E. Blee and A. A. Meyer, of the Tennessee Valley Authority, for example, at the Fifth International Conference on Large Dams, held in 1955, in which they gave details of the results obtained from continuous measurement of detailed settlements on four dams, three of the earth- and rock-filled type, and one earth-filled dam, all constructed between 1941 and 1950. The designers of these particular structures had to allow for earthquake loadings in addition to the normal hazards encountered in all civil-engineering projects of this scale. French engineers have been particularly adept in designing measuring devices of great accuracy, such as the "teleniveau," and other highly accurate instruments which are being installed in the projects now in hand in France and elsewhere in the French Union. Italian engineers, too, have brought the instrumentation of their arch dams to a fine art.

On occasion there have been failures of dams, mercifully few in number, and it would be tragic to think that for the sake of the expenditure of a few thousand pounds — possibly less than one quarter of one per cent of the total expenditure on the projects — the lessons that might be learned by future engineers facing the same type of constructional problem should not become available. Thus there is a strong case for an even greater development in regard to extremely accurate measuring devices for incorporation in the dams now being built.

Electronic engineers have now progressed in their art to the stage where the vital valves, and now the transistors, on which the whole of electronic measurement depends, can be made to be as reliable as any other part of the measuring equipment. For example, the valves assembled in the repeaters, or amplifiers, as they are more commonly called, in the two trans-Atlantic telephone cables put into commission in 1956, are confidently expected to have a minimum life of 20 to 25 years in continuous service. The cost of raising the cable to replace a defective valve would be enormous, and the delay in service might be up to a month in extent. The hostage given to fate is therefore considerable, and the engineers obviously felt that the danger of failure was remote. By the same argument, electronic devices built right into the structure of a dam, and sending out their measurement impulses through cables laid in the concrete, might well enable invaluable data hitherto unobtainable, regarding concrete temperature, internal stresses, fine cracking, and leakage, to be available over very lengthy periods, to the great benefit of the engineers responsible for future hydro-electric developments.

If the question were posed as to who should pay for the installation of equipment perhaps not neces-

sarily needed by the engineers of one particular power company, then the answer is that the whole hydro-electric world would ultimately benefit by the data obtained, and the expenditure should be viewed in the light of a public service. If a dam which will be built in say, 10 to 15 years' time, were to fail or to give rise to severe leakage or operational difficulty through lack of data concerning the behaviour of a dam of the same general design being built now, the conscience of those who may have refused to sanction expenditure on the installation of accurate measuring equipment could not be altogether clear.

The high traditions of public service and professional integrity which have always characterised those concerned with large civil-engineering structures will no doubt lead the majority of chief engineers now engaged in the building of large dams to think of the problems of their successors, and to find a way to help them by making available data which they could accumulate in no other fashion.

Sixth Conference on Large Dams

THE Sixth International Conference on Large Dams will be held in New York in September, 1958, and will discuss the following four questions: No. 20, Heightening of existing dams and methods for the construction of new dams in successive stages. No. 21, Observations of the stresses and deformations in dams, their foundations and their supports; comparison of these observations with the results from calculations and from model tests. No. 22, Methods of compacting, and water content, of materials used for the constructing of the impervious layer and of the filling material in earth and rockfill dams. No. 23, The use of additives and of pozzolanic materials in concrete for dams, and the influence of fine sand.

The Canadian Sectional Meeting of the World Power Conference will be held in Montreal from September 7 to 11, 1958.

Hirakud in Commission

INDIA'S Prime Minister, Mr. Nehru, formally inaugurated the Hirakud dam on January 13, 8½ years after he laid its foundation. The dam is built across the river Mahanadi in Orissa, and is claimed to be the largest earth dam in the world. Of its length of three miles, 3,768 ft. are of concrete and masonry and it has two dykes aggregating 13 miles on the banks of the river. In the deepest section the dam is 200 ft. high. The spillway has 64 12 × 20 ft. sluices. It has the largest and the longest operating gallery ever built in the body of a dam. The main dam, exclusive of the side dykes, is constructed in five sections: (1) masonry power dam, gravity type, 948 ft.; (2) right concrete spillway with masonry transitions, 1,180 ft.; (3) earth dam of zoned-fill type (in the island), 7,540 ft.; (4) left spillway concrete portion with masonry transitions, 1,640 ft.; (5) earth dam of zoned-fill type on the left side, 4,440 ft.

The Hirakud reservoir, with a gross capacity of 6·60 million acre ft., is the biggest so far built in India. Of this the dead storage is 1·88 million acre ft., and the live storage, i.e. 4·72 million acre ft., has to serve three purposes, namely, irrigation, power development and flood control. There are channels on both flanks to provide water for irrigation. Three million acre ft. are required for power development at the dam and at the lower power house as well as to feed the land in the Mahanadi delta. The main-dam power house will have an ultimate installed capacity of 4 units of 37,500 kW each and 2 units of 24,000 kW each, operating under a head of 87 ft. Two of the larger units are yet to be installed. The installed capacity of the subsidiary-dam power house will be 3 units of 24,000 kW each, with provision for a fourth unit. To transmit and utilise this large amount of power, main transmission lines at 132 kV have been undertaken in double or single circuit to different bulk receiving stations. The total length of such 132 kV lines is 418 miles, of 66 kV lines 90 miles, of 11 kV lines 210 miles, and low-voltage lines approximately 700 miles.

Scottish Civil-Engineering Contract

THE Mitchell Construction Company has been awarded a £2¼ million contract by the North of Scotland Hydro-Electric Board for the construction of over 13 miles of tunnels on the Killin section of the Breadalbane scheme in Perthshire. The contract will also include the construction of pipeline aqueduct sections totalling eight miles and the laying of access roads covering many miles. The company will be responsible, too, for the construction of all the associated intake weirs and shafts. Two camps will be built and maintained by the company for the labour force which will total up to 600 men during the peak construction period. The contract will cover three years. The consulting engineers for the project are Messrs. James Williamson and Partners.

The firm recently completed about 24 miles of tunnels on the Board's Glen Moriston and Breadalbane schemes.

Hydro-Thermal Proposal for Washington

IN our August 1956 issue we devoted our leading editorial to a commentary on the power position in the Pacific Northwest, where a serious shortfall of capacity is threatened due to tardiness in securing approval for the requisite hydro development, and we referred to studies being made by the Washington State Power Commission on the possibility of correlating thermal with hydro power.

A specific proposal to this effect was made last August by Ford, Bacon & Davis, Consulting Engineers, New York, and at the request of the Commission they have prepared and published a report. It is proposed to build a 311 MW steam station on the southern shore of Lake Cle Elum, which will be supplied from the adjacent Cle Elum coalfield, said to have economically mineable reserves sufficient to supply a plant twice this size for 100 years.

The plant would be within a few miles of the Federal (Bonneville Power Administration) high-voltage transmission line, and would operate in conjunction with BPA with whom a contract for the purchase of hydro power would be concluded. This would have the effect of firming up secondary hydro-power and would enable the Commission to offer for sale power that at present is largely wasted. An estimate by BPA indicates that by 1963-4 the secondary power available in the Federal system will be of

the order of 2,100 MW, of which 700 MW will be available from 30 to 60% of the time. Much of this energy will be wasted unless additional storage is provided on the Columbia River or a hydro-thermal correlation of the kind projected is effected.

Full integration between the Commission's proposed steam plant and BPA hydro would enable the Commission to offer for sale an increase of about 50% in power over and above the maximum steam capacity installed. This is due to the ability of a properly co-ordinated hydro-thermal system to "store steam power in the reservoirs."

The economic and financial implications are set out very competently in the report, and it is shown that utilities of the area would be able to purchase firm power from the Commission at a cost which, while somewhat higher than present purchases from Federal agencies, would be as low as or lower than that from some of the new hydro installations that are available, or are now being considered for development. An outstanding advantage to the purchaser would be that under the Commission's plans it would be possible to buy power at a constant price; this would be a form of insurance against having to meet heavy costs when hydro production is low.

The feasibility of the project will, of course, depend on such financial factors as the receipt of fuel at a satisfactory price, on the completion of contracts to sell power to the utilities, on the conclusion of a concontract to buy hydro power from BPA, and on financing at reasonable rate of interest. We understand that negotiations on all these necessary matters are in progress.

Large Kaplans for Sweden

THE Swedish State Power Board has placed an order with Nydqvist & Holm A.B. for two Kaplan turbines for the Porsi power station on the Lule River in northern Sweden. These will be the largest turbines of their type to be installed in Sweden. Each will have a maximum output of 131,000 h.p. at 115 r.p.m., and will operate on heads ranging from 33 to 36 m. Porsi station is scheduled for completion in 1960-61 and will have an annual output of 960 million kWh. Space will be provided for a third set of similar capacity.

More Oil-Filled Cable for Kemano

PIRELLI-GENERAL Cable Works Ltd. has received a third order for oil-filled cable for the hydro-electric power station at Kemano, British Columbia, of The Aluminum Company of Canada Limited. The contract covers the manufacture and installation of a complete three-phase circuit comprising over 6,000 ft. of single-core 0·4 sq. in. 301 kV oil-filled cable and accessories. The cable will run through a tunnel 670 yards long from the power station to the terminal of the overhead line which transmits the power to the electrolytic refining plant at Kitimat, 50 miles away. It will be identical with the two previous Pirelli-General installations for the Kemano-Kitimat project, the second of which was completed in September last year.

This latest order, to the value of approximately £50,000, was secured in the face of vigorous competition from Canadian cable manufacturers. All negotiations in connection with the contract were carried out in Canada on behalf of Pirelli-General by the Amalgamated Electric Corporation Limited, Ottawa.

Finland's Newest Station

FINLAND'S latest station on the Oulu river at Utanen commenced service with one unit last November, and according to schedule should be operating at full capacity with three 55 MW units by the time this note is published. It is situated between the Nuojua plant upstream and the Pälli plant downstream, and operates on a head of 15·7 m. The river at Utanen has a catchment area of 20,605 sq. km., a mean flow of 250 cu. m. per sec., a maximum flood of 800 cu. m. per sec. and a minimum flow of 63 cu. m. per sec. The dam, which incorporates the power station, is a concrete structure 172 m. long and 16 m. high, and contains two spillway openings 14 m. wide by 6·5 m. deep controlled by tainter gates. A tailrace 11·5 km. long had to be excavated, 27 m. wide at the bottom of the channel and designed for an average depth of water of 14 m. The turbines are Kaplan machines, and the station feeds the 220 kV Finland network.

Power Developments in N.S.W.

CONSTRUCTION of a major power-distribution centre at Yass, of which the initial development will cost A£2 million, will be started shortly by the Electricity Commission of New South Wales. The new Yass centre will combine the functions of a switching station for the new 330 kV transmission system, and a substation to step down the voltage for distribution throughout the south-west of the State.

The 330 kV transmission system—already under construction—will interconnect the Snowy Mountains hydro-electric stations with the major thermal stations on the N.S.W. coalfields. It will be the highest-voltage power transmission system yet to be used in Australia. The first section, temporarily operating as part of the 132 kV system, links Goulburn with Tallawarra power station (near Port Kembla). A second section between Goulburn and Yass is now under construction, and next year the line will be extended to the Tumut area to link up with the first of the major hydro stations of the Snowy scheme. It will also continue to Sydney, Lake Macquarie, and the north-west of the State.

The Yass 330/132 kV substation will step down the supply from 330 to 132 kV for distribution on the network to Cooma, Goulburn, Wagga and Burrinjuck (replacing the temporary switching station erected at Yass to control those lines). The substation will include the largest transformer banks installed in Australia, together with the switchgear required for their control and the control of the transmission lines.

Extensions of the 132 kV system from Wagga both to Albury and to the Murrumbidgee Irrigation Area are in progress and surveys are being carried out for the construction of further new sections between Cowra and Forbes (to begin this year) and between Yass and Cowra. The existing Yass-Cooma line will

be connected to a new substation being built at Queanbeyan to supply the surrounding district, including Canberra. Yass will also be developed as a major depot for the south-west area, and the building plans include the construction of new workshops and offices from which maintenance and repair work will be supervised. As a 330 kV switching station, Yass will control a section of the new extra-high voltage transmission system which in a few years will extend from the Victoria border to the north-west of the State.

This system is required not only for the transmission of power from the Snowy Mountains hydro-electric stations, but from the very large thermal power stations now being established mainly on the coalfields, which will continue to provide the greater part of the electrical energy required.

The south-west construction work, therefore, will not only be extended to supply cities, towns, farms and industries throughout the district, but forms part of the pattern of State-wide development by which the combined power resources are being linked in the interests of the most economic and reliable supply to consumer throughout New South Wales.

A New British Columbia Survey

A MEMORANDUM of Intent has been signed between the Government of British Columbia and the Wenner-Gren Foundation regarding the building of a monorail railway from a point near Fort McLeod to the Yukon Border. This railway is proposed in conjunction with a survey which the Wenner-Gren British Columbia Development Co. Ltd. will undertake in relatively unknown territory in the Rocky Mountains Rift about 500 miles from Vancouver and south of the Yukon Border. A sum of $5 million has been earmarked for this survey, which will cover hydro-electric, mining and forestry resources.

As technical advisers the Wenner-Gren Company have appointed The British Thomson-Houston Export Company, who will have a two-fold task: (i) to prepare the assessment of the hydro-power potential of the area on the basis of which individual projects will be undertaken both as regards design and execution, and (ii) as electrical advisers to The Wenner-Gren British Columbia Development Company in respect of electrical requirements of their interests. The work to be done by the BTH Company in assessing the power potential of the area will be in collaboration with Canadian engineering interests, and will be done concurrently with a mineralogic survey by The Lundberg Exploration Company, who were responsible for prospecting the iron-ore deposits in Labrador, and with a forestry survey which is being carried out by the Ranking Company of Montreal in collaboration with the Hedlunds Travaru Company of Sweden. These surveys are all to be completed within 18 to 24 months. Most of the survey work will have to be done by aerial facilities as there are no roads. These surveys will establish the potential resources of the area which are suitable for development, and these initial surveys will be used as the basis for preparing the development programme which will be submitted to the British Columbia Government for their approval.

The power area is some 470 miles long and varying in width from 50 to 150 miles with an approximate total area of 50,000 square miles. It covers the upper reaches of the Peace River, including the Finlay, Omineca and parts of the Parsnip River, and the catchment of the Ketchika River, a tributary of the Liard, which in turn flows into the Mackenzie.

Scottish Hydro Radio Link

THE North of Scotland Hydro-Electric Board has put into operation a two-way radio link to allow continuity of contact with their mobile units at work in the North-East of Scotland. A control point has been installed in the operational control room of their Aberdeen Area office. This operates in conjunction with a fixed base station on high ground at Cairn-mon-Earn. The equipment at Cairn-mon-Earn consists of a 70 ft. mast and a "talk through" radio, which allows the messages from Control in Aberdeen to be automatically re-broadcast to the radio-equipped vehicles. Cairn-mon-Earn base station has proved on survey to cover the full Aberdeen service area. The equipment in use in this area was manufactured by Pye Radio Limited and is similar to equipment already installed in other major hydro-electric schemes. Its value in this area has been well tested over the more difficult months of winter operation when snow, wind and storms combine to make normal road travel difficult. It will also allow very considerable economies to be made in time and effort, as previous communication involved travel to the nearest telephone point and occasionally the telephone lines were down. Apart from such normal routines the radio link will have the obvious advantage of meeting any emergency which may arise at any of the constructional sites.

BTH Secures £2½m. Contract for Spain

THE British Thomson-Houston Co. Ltd. has secured an order valued at over £2,500,000 for the supply of hydro-electric plant for the Belesar and Eume power stations of Fuerzas Electricas del Noroeste, S.A. (Fenosa) of Coruna, Spain. For both stations material to be supplied includes water turbines, sub-contracted to Boving & Co. Ltd., waterwheel generators with associated transformers, 220 kV and 132 kV switchgear and power-station switchgear and control gear.

Belesar will comprise three 88,000 kVA, 11 kV, 214 r.p.m. vertical generators, driven by 104,800 h.p. Francis-type turbines. The output of the generators will be stepped-up for distribution at 132 kV in Fenosa's system in Galicia, and for export at 220 kV to the centre of Spain. The outgoing circuits will have BTH air-blast circuit-breakers at 220 kV and bulk oil breakers at 132 kV.

At Eume power station two 32,000 kVA, 11 kV, 600 r.p.m. vertical generating units will be installed, also driven by Francis turbines. This station is between Coruna and Ferrol and the generator output will be stepped up for distribution in the 132 kV network. BTH will supply the transformers, switchgear, and control gear associated with this power station.

The order also covers 132 kV and 66 kV oil circuit breakers, and step-down transformers for the extension of a BTH-equipped substation at El Troncal, near Vigo.

Fig. 1. The new Eildon dam and power station

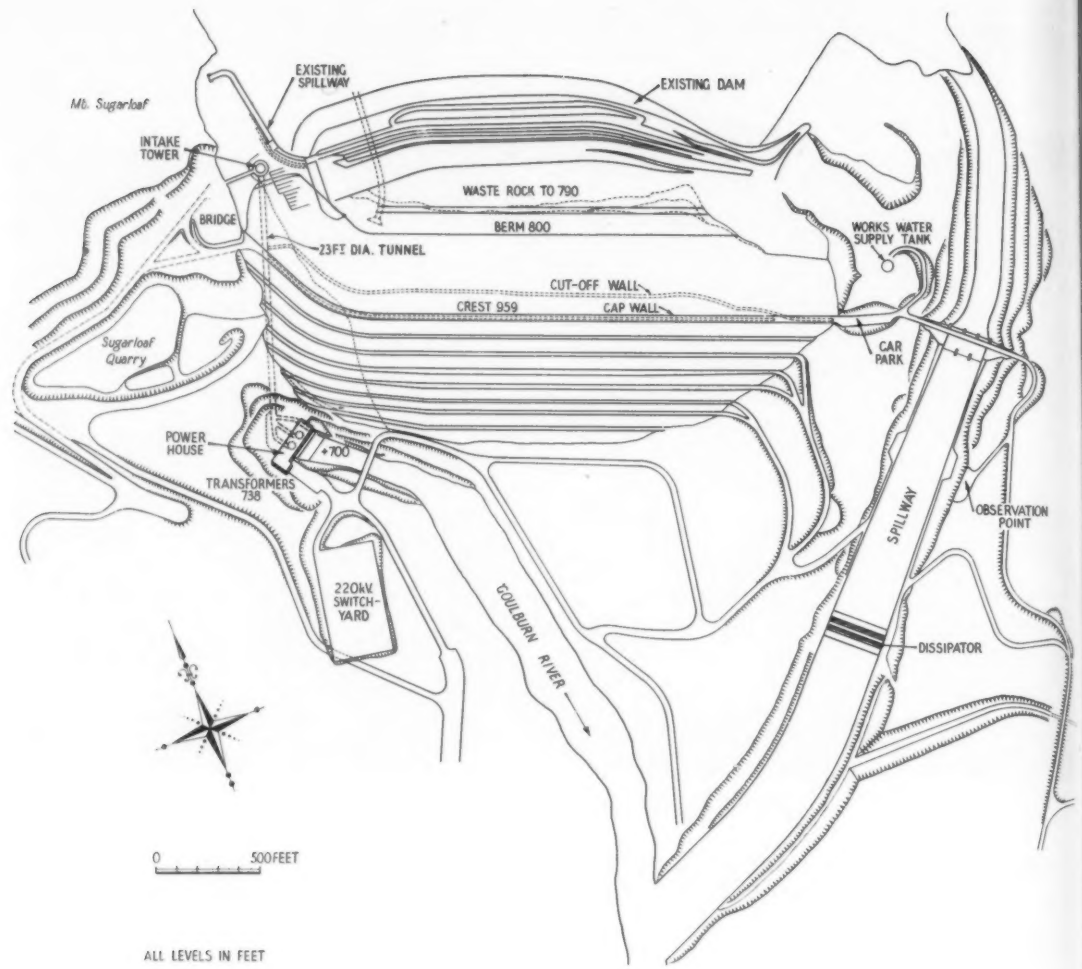
Enlarged Eildon Irrigation and Hydro-Electric Scheme

A notable Australian project for more intensive use of the waters of the Goulburn River at Eildon Reservoir in Victoria for irrigation and the generation of hydro-electric power is now nearing completion

EILDON reservoir is located about 62 miles north-east of Melbourne at the junction of the Delatite River with the Goulburn River, which is the largest river in the State and flows north into the River Murray. With the completion recently of one of the largest earth and rockfill dams yet built in the world, the State Rivers and Water Supply Commission has enlarged the capacity of the reservoir from 306,000 acre-ft. to 2,750,000 acre-ft. to provide additional water for irrigation in the Goulburn Valley in north central Victoria. This enlargement has made possible a great increase in the generation of hydro power at Eildon dam by the State Electricity Commission of Victoria. Where formerly there was a power station of 13·6 MW capacity operating on the waters of the original reservoir, there will now be a power station of 136 MW.

The primary purpose of Eildon reservoir is to provide water for irrigation. Generation of electricity at Eildon power station is, therefore, mainly governed by irrigation requirements, but provision has been made for limited operation of the power station in the winter months (when no irrigation water is flowing).

The new Eildon dam is complete, and the new Eildon power station has been in partial operation since August, 1954, with two small generators, each of 8 MW capacity, in service. Two 60 MW turbo-generators are scheduled to come into service; one is now in commission and the other is due to come into operation this month. The new Eildon power station, like the former Sugarloaf power station below the old Eildon dam, is an integral unit in the State Electricity Commission's interconnected generating system, which now comprises 18 steam, hydro and diesel power



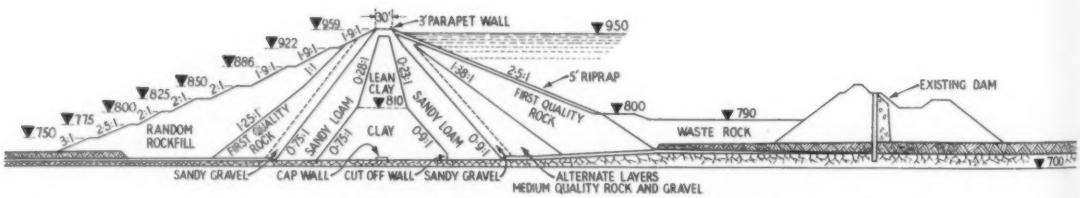


Fig. 2. Plan and elevation of the new Eildon dam

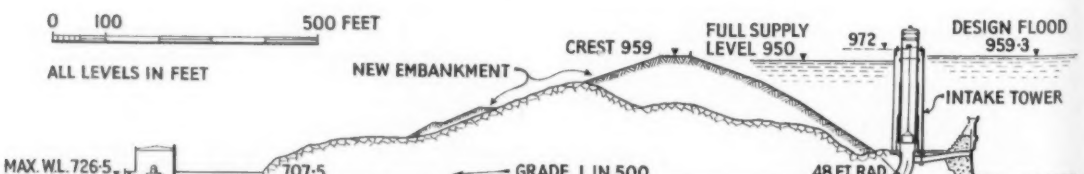


Fig. 3. Section through intake, penstock and power house

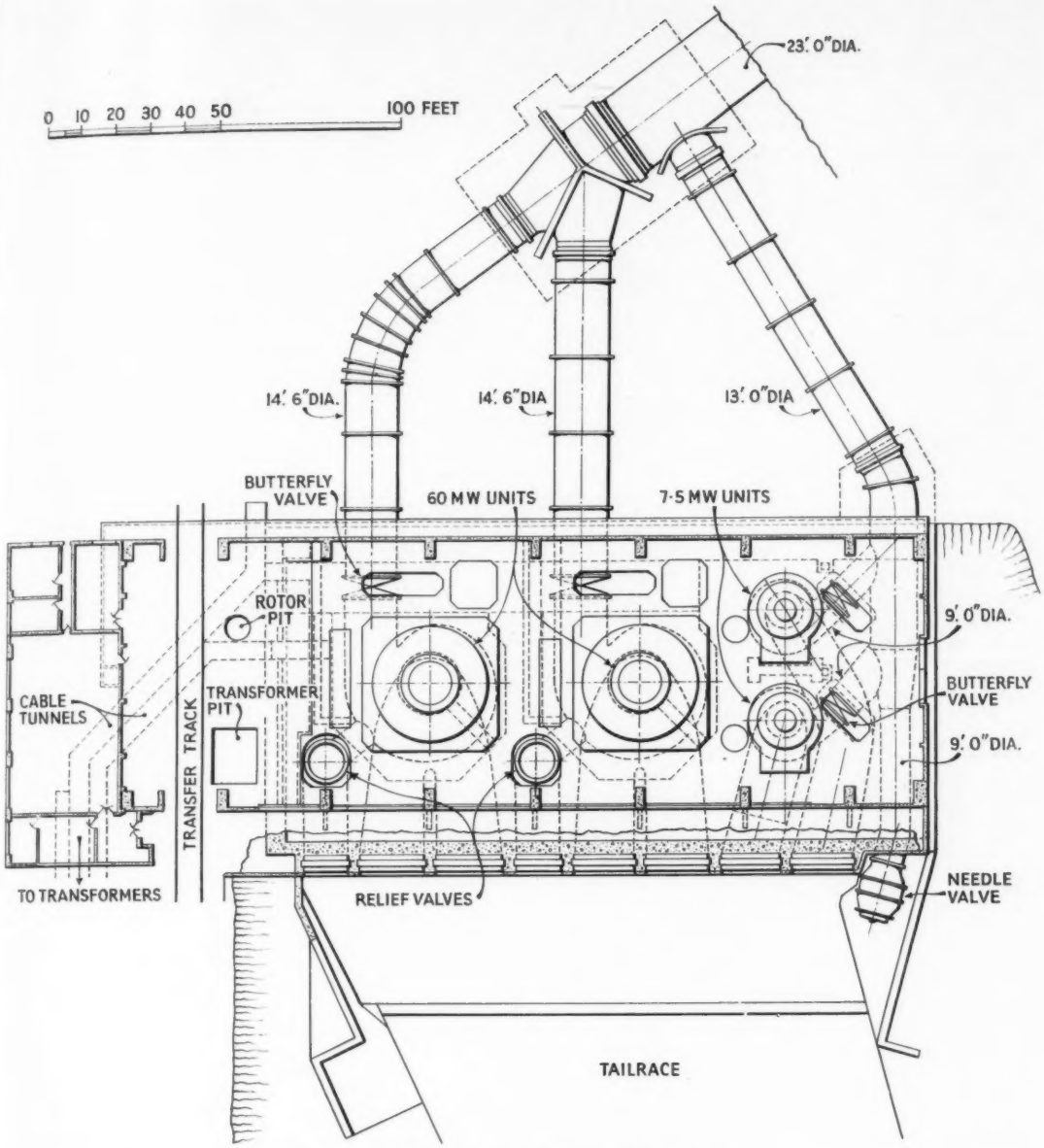


Fig. 4. Plan of the new Eildon power station

stations together generating virtually the whole of Victoria's electricity and serving a network which supplies approximately nine-tenths of the population of Victoria.

The State Rivers and Water Supply Commission designed the dam, outlet works and detention pondage weir. The detailed design of the power station was carried out by Balfour Beatty of London to the requirements of the State Electricity Commission. The complete construction work, including the power station, was carried out by Utah Construction Ltd., formed as an Australian subsidiary of the parent Utah Construction Company of San Francisco.

The old Eildon development consisted of an earth dam (top of Fig. 2). Associated with it was Sugarloaf power station (at right of Fig. 3), in which were installed two vertical-shaft Francis turbine-driven alternators, each of 6·8 MW output at a net head of 110 ft., but designed so that they might operate later at 160 ft.

To meet the need for additional supplies of water for the Goulburn irrigation districts, investigations were begun in 1940 by the State Rivers and Water Supply Commission to determine the most economical method of obtaining additional storage capacity in the Goulburn River catchment. It was recommended that an earth and rockfill dam and appurtenant works should be constructed immediately downstream of the existing dam, the new structure to be approximately 250 ft. high and the capacity of the reservoir 2,350,000 acre-ft. This recommendation was approved by the

Victorian Government on April 28, 1949. Later, following discussions with the State Electricity Commission, it was decided to increase the height of the dam to 260 ft. and the capacity of the reservoir to 2,750,000 acre-ft. The 400,000 acre-ft. of extra storage would ensure, even under drought conditions, a minimum of 42,000 acre-ft. of water each year to be drawn upon at any time by the State Electricity Commission. This would be of particular value during the winter months of May to August, when electrical power demands are at a maximum and water is not being released for irrigation.

It was also decided that the outlet from the reservoir should be located so as to provide a dead storage of 100,000 acre-ft., thereby ensuring a minimum head of 80 ft. at all times, the State Rivers and Water Supply Commission agreeing not to draw from the reservoir for irrigation purposes below 200,000 acre-ft., and to begin the winter storage with at least 242,000 acre-ft. in the reservoir. Further, a detention pondage weir was to be built two and a half miles downstream of the main dam to provide for the regulation of diurnal discharge variations from the turbines.

Subject to these modifications to the irrigation works, together with an increase in the tunnel diameter to 23 ft., the State Electricity Commission planned to install two 60 MW turbo-generators in the new power station, and it was agreed that the relief valves for the 60 MW turbines would be available for use as by-passes in the unlikely event of one or both turbines being closed down for maintenance or repairs during the irrigation season.

Details of Plant

It was also decided to re-install in the new Eildon station the two small units from the old Sugarloaf station to obtain additional power at low reservoir heads. The Brown-Boveri generators being amply designed, and the available head now being higher, these sets were up-rated to 8 MW each. The suppliers of the turbines, Boving & Co. Ltd., provided new runners for operation at heads up to 180 ft. and new inlet valves, since these would have to withstand a static head of 242 ft.

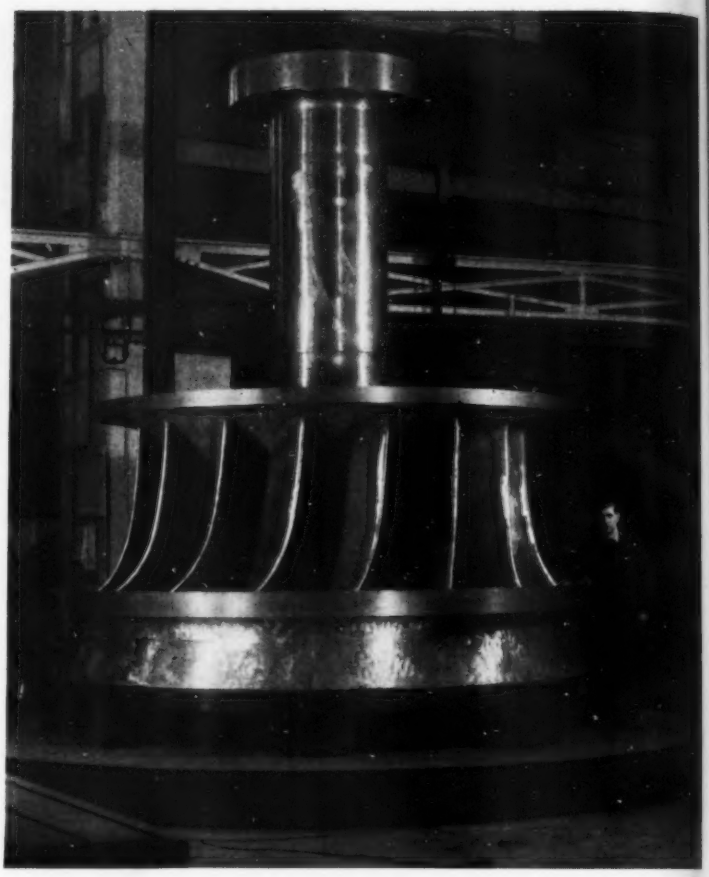


Fig. 5. Runner of one of the Boving 82,200 h.p. turbines

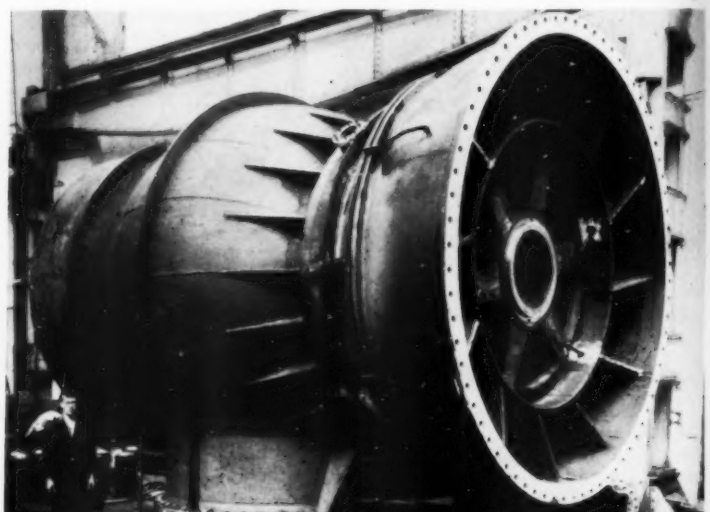


Fig. 6. Relief valve for first turbine

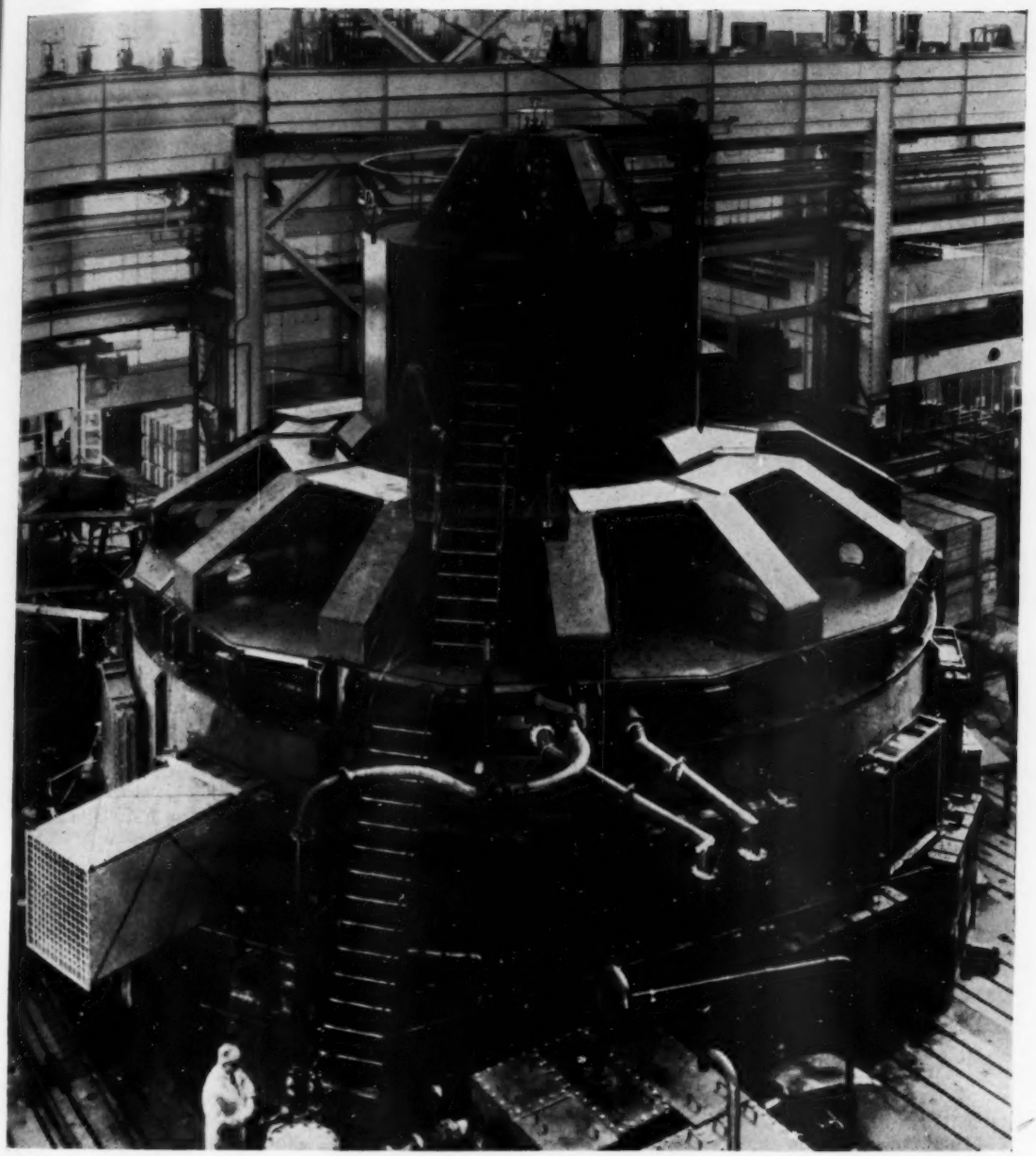


Fig. 7. One of the B.T.H. 11 kV 66,670 kVA 150 r.p.m. alternators on test

The tunnel and penstock layouts are shown in Figs. 3 and 4. The 9 ft. diameter needle valve was used as a diversion outlet during the final phase of building the dam. It was later disconnected and a blank flange fitted. The intake tower was equipped by Fried. Krupp.

The turbines for the 60 MW sets are being supplied by Boving & Co. Ltd., of London and Melbourne, and are of the Francis type, each developing 82,200 b.h.p. at a net head of 235 ft., and a speed of 150 r.p.m., and each provided with two interchangeable runners, one for net heads between 77 and 150 ft., and the other for net heads between 150 and 235 ft. The spiral-casing inlet diameter is 14 ft. 6 in. and the casings are of fabricated construction, welded at site.

The generators have been supplied by Australian Electrical Industries Pty. Ltd., Melbourne, as sub-contractors to Boving & Co. Ltd., and have been manufactured at the works of the British Thomson-Houston Company at Rugby. Each is rated at 60 MW (66,670 kVA at 0·9 power factor) 11 kV and has a lower guide bearing and a combined upper guide and thrust bearing.

Although the generator rotor weighs 280 tons, the power station is equipped with a crane of only 75 tons

capacity. Each rotor was assembled on its shaft and spider in its final position. The stator was placed around it in two halves and the joint coils inserted. Stator coils can be replaced or repaired in the space made available by removing some of the rotor poles, and all parts of the turbines can be removed through a passage in the generator foundation or by dismantling downwards and removing them via the runner hatch. This arrangement has made possible considerable savings on the cost of the crane and on that of the reinforced-concrete columns and beams of the power station building.

Electrical Works

Each generator will be connected directly to its own transformer via an open tubular bus run in a tunnel from machine to transformer. The bus consists of one 3¼ in. outside-diameter copper tube per phase and the tunnels will be forced air cooled. Originally, it was proposed to use two circuits per machine, but due to the comparatively low load factor of the station (21·6 per cent.) it was found that, by the adoption of forced cooling and elimination of one conductor, an overall economic saving could be achieved. At full load the lead losses will be 25 and 50 kW, respectively, the connections from one machine being approximately twice as long as those from the other.

Each of the two banks of main transformers, supplied by the British Thomson-Houston Co. Ltd., consists of three single-phase units, each 11/129·9 kV ratio (delta/star connected) and rated at 22·5 MVA, giving a three-phase bank rating of 67·5 MVA. One spare single-phase unit is provided as standby to the two banks.

A short length of 220 kV overhead line will convey the output to the nearby switchyard, using a conductor of 54/7/·1291 in. steel-cored aluminum which is the same as that used for the Kiewa-Melbourne transmission line. It is to be carried on two steel towers of double-circuit vertical construction, the total route length being 840 ft. As the feeders from the power station are quite short and the machine transformers are within view from the switchyard, it was considered unnecessary to provide any switching at the transformers. The 220 kV switchyard will consist of a conventional double bus with bus-tie circuit breaker, and the incoming power-station circuits, one to each bus, will be switched by 220 kV circuit breakers of the minimum-oil type, and of 3,500 MVA rupturing capacity, to be supplied by Reyrolle Ltd.

The switching station at Eildon, as well as serving to connect the power station to the 220 kV system, is also necessary to maintain stability on the main 220 kV transmission line from Kiewa to Melbourne. The Kiewa group of hydro stations, which will have a total capacity of about 300 MW, of which 90 MW is already in service, is located about 150 miles from Melbourne, and the Eildon switching station, situated on the route of the 220 kV line some 62 miles from Melbourne and 87 miles from Kiewa, is well sited as an intermediate station for stability purposes. Thus, at the switching station, there will be two incoming circuits to Melbourne, all of which will be independently switched. Both incoming and outgoing transmission will consist of steel tower lines of double circuit vertical construction employing 54/7/·1291 in. steel cored aluminium conductor.

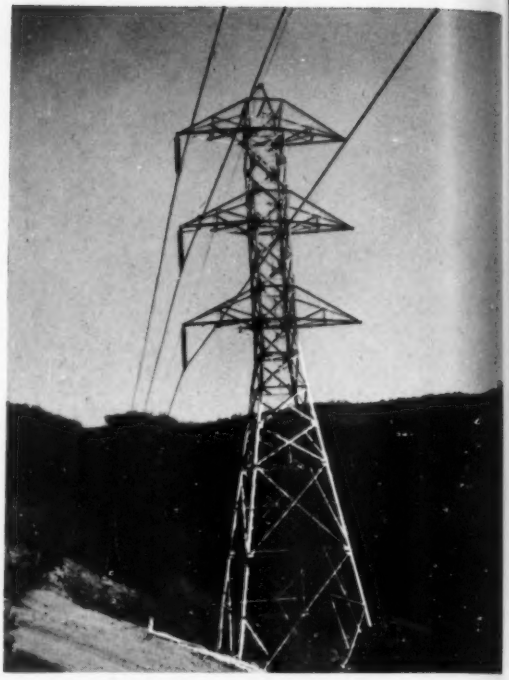


Fig. 8. 220 kV line near Eildon reservoir

Acknowledgment

This article was written specially for WATER POWER by the State Electricity Commission of Victoria, and we are happy to express our indebtedness to the Commission for their collaboration.

The Brussels Exhibition

The 1958 World Exhibition which is being held at Brussels from April 17 to October 19, 1958, will be the first major international exhibition since the war and will be the largest of its kind ever to be held. The site, at the Heysel on the North Western outskirts of Brussels, is 3½ times the area of London's Hyde Park and it is expected that at least 30 million visitors will attend from all over the world. The British Section will consist of two pavilions, one, arranged and paid for by the British Government at a cost of over £500,000; and a larger British Industries Pavilion entirely the responsibility of British Industry. This second pavilion is being organised by British Overseas Fairs Ltd. on behalf of the Federation of British Industries. In the British Industries Pavilion the aim is to present a fully representative picture of British Industry and the British Electrical and Allied Manufacturing Industry, which exported £272·5 million in 1956, will feature prominently. In fact the collective exhibit being organised by this industry will be the largest single stand in the Pavilion. The Atomic Energy Authority will also be exhibiting, so Britain's contribution to the peaceful application of atomic power will be well to the fore.

Fig. 1. Stage 1—upstream and downstream legs of cofferdam nearing completion

Chippawa-Grass Island Pool Control Structure

Dr. R. L. Hearn's account of the Sir Adam Beck-Niagara G.S. No. 2 in our July, 1956, issue discussed the general problems involved in planning and construction of the development. The following article describes briefly a cofferdamming operation carried out in the swift water above the Falls

By J. L. SOARE, B.Sc., C.E., P.Eng.,
Project Engineer, Niagara River Remedial Works

EARLY hydraulic model studies in connection with the design of the remedial works for the preservation and enhancement of Niagara Falls and the river, as required by the Treaty of 1950, revealed that a control structure would be required upstream from the cascade section of the Niagara River to compensate for the increased diversions from the river and to enable the existing relation between the river flow and the level of the Niagara River at the Grass Island Pool to be maintained. For this purpose, the Chippawa-Grass Island Pool Control Structure was decided upon with thirteen 100 ft. wide sluices separated by 14 ft. wide piers.

In planning the construction of this control structure it was recognized that precautions had to be taken to ensure that the existing river levels would not be affected during the construction period sufficiently to interfere with upstream interests. This condition could be ensured only by carefully scheduling the extension of the structure out from the shore in increments of lengths sufficient to compensate for the increasing diversions through the Sir Adam Beck-Niagara G.S. No. 2 intakes as new units came into service.

To this end hydraulic model studies were carried out in order to establish a schedule for the construction of the control structure. It was decided that the structure could be completed in six stages, in the manner indicated in Fig. 5. The schedule proposed that the first two sluices and the shore abutment would be enclosed by the first-stage cofferdam. The construction of the first two sluices was planned to proceed as the cofferdam to enclose the second-stage area, to be

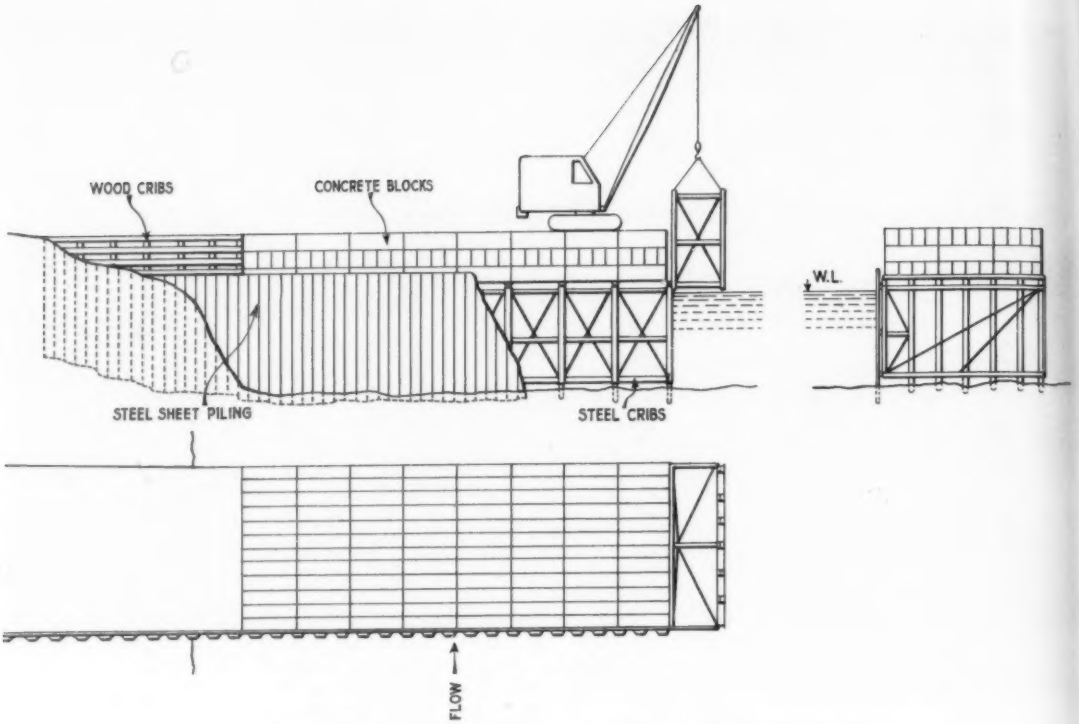


Fig. 2. Diagrammatic sketch of method of crib placement

occupied by the third and fourth sluices, was extended. On completion of the first two sluices it was proposed to remove the cofferdam from the first stage and place the first two sluices in full operation. This procedure would then be repeated for the third stages (three sluices) and in turn for the remaining stages (two sluices each) until all thirteen sluices were completed.

The repetitive nature of the schedule suggested that a cofferdam which could be re-used would be desirable. As far as could be determined the bottom of the river was reasonably level and it appeared that approximately the same height of cofferdam could be made to serve each stage. Keeping in mind the high velocities and the turbulent flow in the river, a type of re-usable steel cofferdam was devised which proved to be eminently satisfactory.

Immediately adjacent to the shore, extending out into shallow water, a section of the cofferdam was built using rockfilled timber cribs of conventional design. Beyond this structure, steel cribs top loaded with concrete blocks were used. The cribs and the method of placing are illustrated in Fig. 2 and Fig. 3 shows a crib section set up for loading tests in the dry.

Each crib is 10 ft. by 30 ft., and was lowered into place adjacent to the one previously placed by means of a crawler crane. A series of interlocking rollers kept the crib in alignment with the previous one, and the crib was lowered until close to the bed of the river, its 30 ft. dimension being upstream and downstream.

After it was placed, heavy H-sections were inserted in the crib and lowered until they were in contact with

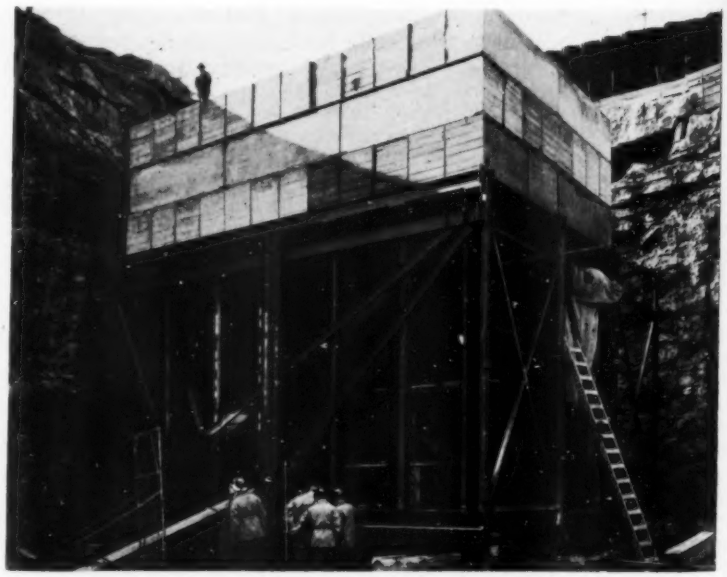


Fig. 3. Crib section ready for loading test in the dry

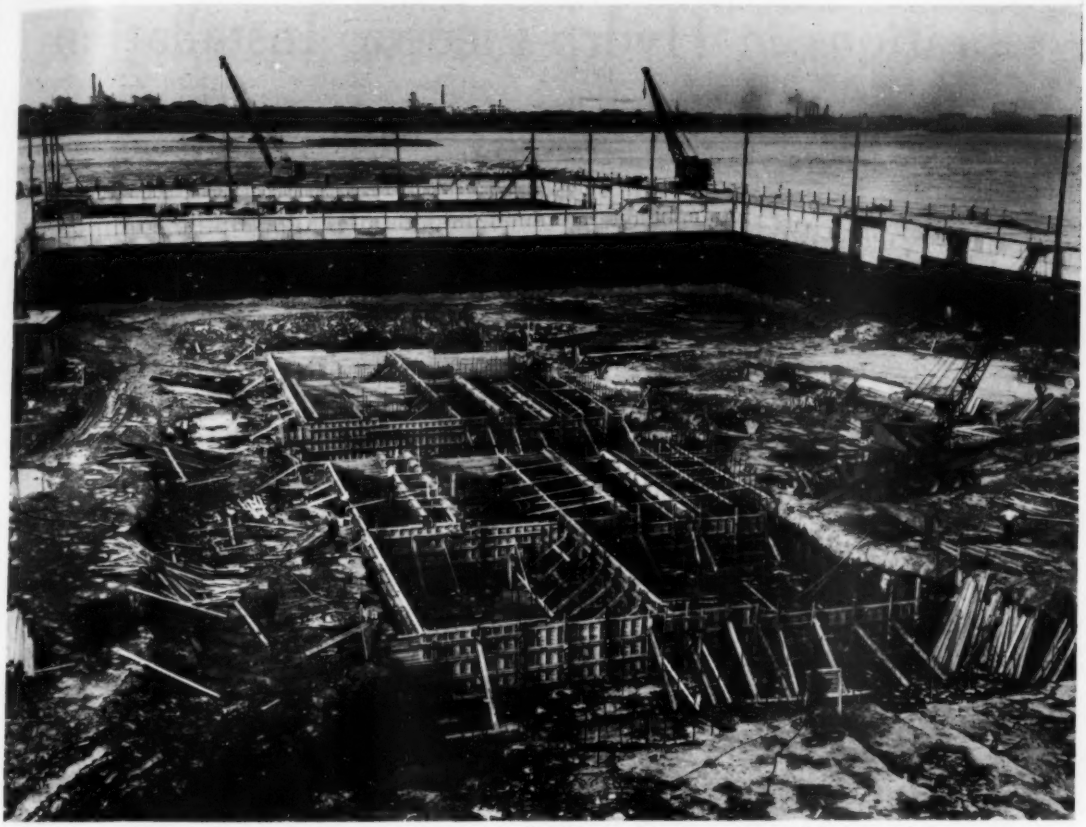


Fig. 4. Construction inside Stage 1 cofferdam proceeds as Stage 2 is extended

the river bed. They were then driven to secure good contact. The portion of the H-sections projecting above the top of the crib was then cut off at the proper level and a capsill beam spanning the H-sections was fastened in position. The crib was then loaded with 36 precast concrete blocks, each 10 ft. x 2½ ft. x 3 ft. and weighing 6 tons, resting on the capsill beams. Thus the top loading was carried, not by the crib, but by the H-sections. The crib served as a spacer and aligner for the H-sections and distributed the horizontal shear.

Crib placing continued in this manner until both the upstream and downstream legs of the cofferdam were completed, and the section joining their extreme ends was built following the same procedure. Steel sheet piling was then driven on the river faces of all sections of the cofferdam, penetrating the limestone bed perhaps 2 or 3 in. An earthfill along the base of the cofferdam provided a watertight seal. In this manner stage No. 1 was completed.

Each succeeding stage has been successfully completed in a similar manner with no unexpected difficulties. The cofferdam has proved to be exceptionally tight and each stage has been pumped dry in the course of one day. Leakage after unwatering is handled by a small pumping unit.

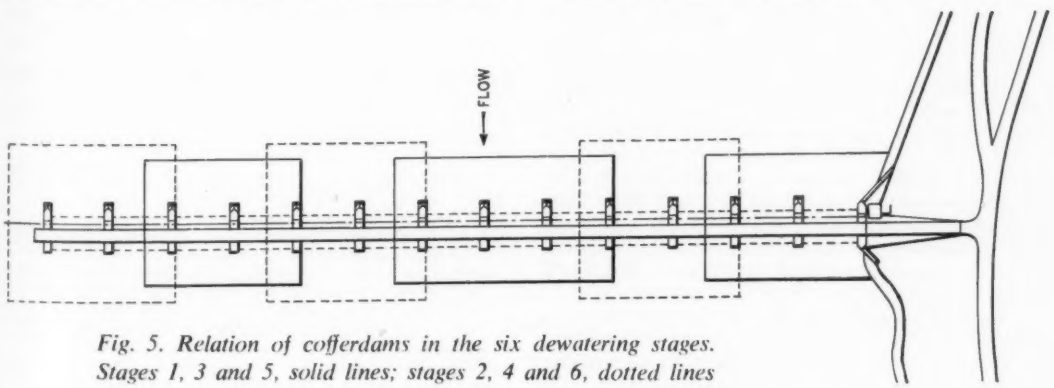


Fig. 5. Relation of cofferdams in the six dewatering stages. Stages 1, 3 and 5, solid lines; stages 2, 4 and 6, dotted lines

Vibrations in Hydro-Electric Installations

By SERGE LELIAVSKY, Ph.D., M.I.C.E., M.Am.Soc.C.E.

PART ONE

ACCORDING to the latest practice adopted in modern designing offices—e.g., the U.S.A. Bureau of Reclamation—a power house for hydraulic turbines, generators and associated equipment, is first calculated for static forces, such as water pressure, structural and machinery weights, etc., and thereafter, the stability and resistance of the structure are verified for the effect of vibrations. The reason for adopting this particular order of procedure will be self-evident from the explanations given in the following pages.

There is a rather curious point in this connection, which may possibly deserve being emphasised, viz., the particular attitude which is occasionally adopted by civil designers when referring to, or dealing with, the vibration problem; in fact vibrations of structural works are not infrequently regarded as an almost unpredictable phenomenon, endowed with some uncontrollable, magic destructive power. Such an attitude is, of course, emotional rather than rational; that is, it is not a reasoned approach but a subconscious, intuitive feeling, which may nevertheless cause much doubt and apprehension, and can have an adverse influence on the results produced by the designer.

On the face of it, such a feeling may not be very difficult to explain, for, although the theory of vibrations is not entirely *terra incognita* for a civil designer, this theory as such, belongs to mechanical engineering. Proof of this may be found in the fact that the number of recent papers on vibration read before various societies and institutes of mechanical engineers, exceeds many times the number presented to similar bodies of civil engineers.

Since these notes are written indiscriminately, to be read both by the mechanical and the civil man, the former may perhaps find some of the explanations too elaborate, and even superfluous. In the circumstances, however, this cannot very well be avoided.

Our basic approach to the vibration problem is based, essentially, on the coincidence (or otherwise) in time of two basic types:

A. Free (or "natural") vibrations.

B. Forced vibrations.

The A type occurs after a suddenly applied force—or other cause which has disturbed an elastic system from its position of static equilibrium—has ceased to be effective. Such vibrations are, consequently, maintained by the inner elastic forces of the system alone, and though their intensity, i.e. amplitude, is a function of the magnitude of the external disturbing force, their period, i.e. frequency, depends solely and exclusively on the elastic system alone; in fact this frequency—usually described as the "natural frequency"—is a characteristic parameter of that system.

If, now, we consider the B type, i.e. the vibrations produced by the application of an external periodic force which continues to be effective, we shall find that their frequency is, of course, the same as that of the force, but their amplitude is a function of both the force and the relation between:

a—the frequency of that force, and

b—the natural frequency.

It follows, therefore, that the latter frequency is a basic parameter for all types of vibrations; in fact, even a very slight periodic external force—provided its frequency approaches the natural frequency of an elastic system—may eventually produce very serious, or even dangerous, vibrations in that system. Little wonder, therefore, that the calculation of the natural frequency period is one of the main problems of vibration engineering.

In explaining its general method, text-books usually consider [1] the case of a weight, W, held in suspension by a spring (Fig. 1), which is, indeed, the simplest elastic system that can be imagined.

It must be fully understood that the elementary device shown in this sketch does not interest us as such, but is only a convenient diagram for explaining the symbols which will be used later on in the equations for the vibration of structural elements in hydro-electric power houses; namely, as follows:

k = load producing unit extension (or deflection) of the structural element, or elements, involved;

W = weight or load;

δ = static deflection due to W;

S = force in the spring;

t = time;

p = constant $\sqrt{g/\delta}$ for a system;

g = acceleration of the force of gravity;

T = period of vibration;

x = ordinate (vertical or horizontal) determining at any time the position of the weight in space; the system possessing, by postulate, one degree of freedom only;

$\frac{dx}{dt}$ = velocity;

$\frac{d^2x}{dt^2}$ = acceleration;

W/g = mass;

q = weight per unit length of spring or beam;

l = length of same;

$a\frac{dt}{dx}$ = damping force;

$\frac{ag}{2W} = C$ = damping factor;

[1] E.g., B. B. Low, "Mathematics," p. 414, S. Timoshenko, "Applied Elasticity," p. 312, and many others. The author takes this opportunity to emphasise the advantages of Prof. Timoshenko's treatment of the problem, not only because of its deep insight and erudition, but also, because Prof. Timoshenko is essentially a civil engineer, and his method cannot fail to appeal to all civil men. The writer is largely indebted to him both for the theory presented in these pages and for the Figs. 1 to 4 (see as above).

In explaining to civil engineers the principle of a mechanical device—whether in the schoolroom or in the office—the writer has frequently found it convenient to use d'Alembert's principle, because it permits any case of dynamic equilibrium to be converted into that of static equilibrium, and it is in this latter type of problem that the civil-engineering designer is particularly efficient. In fact, in its simplest form, d'Alembert's principle comes down to saying that in considering a moving system it suffices to add the so-called "inertia forces" to the usual static forces, in order to obtain the same condition of equilibrium as if the system were at rest. The "inertia forces" are the masses multiplied by the relevant accelerations. It should be noted that these forces are used here with the negative sign, i.e. applied in the opposite direction, as compared with that adopted in calculating the acceleration.

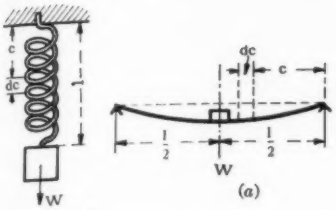


Fig. 1

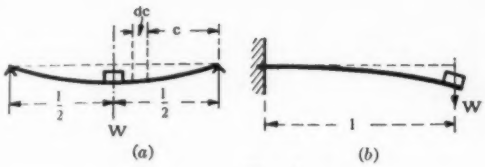


Fig. 2

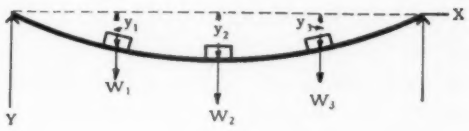


Fig. 3

In our case, assuming the displacements to be positive when they are downwards (see Fig. 1), the force in the spring, S, is the algebraic sum of the weight, W, and of the inertia force,

$$-\frac{W}{g}\frac{dx^2}{d^2t}$$

$$\text{Hence} \quad S = W - \frac{W}{g}\frac{d^2x}{dl^2}$$

Let the origin of x coincide with the average position of the load, viz., the static position in which it would have remained had there been no movement at all. The force acting in the spring would then have been equal to W and the condition of static equilibrium would have prevailed.

It is next assumed that due to some external physical cause this state of static equilibrium is destroyed and that the load is, consequently, at a distance x from its neutral, average position. In addition to W we shall have, in this case, another "elastic" force which will be proportional to the extension x of the spring, viz., kx. Thus, the total force in the spring will now be equal to

$$S = W + kx$$

Equating the two formulae for S we obtain the basic equation for the case

$$W - \frac{W}{g}\frac{d^2x}{dt^2} = W + kx$$

This formula is usually rewritten as follows:—

$$d^2x/dt^2 + p^2x = O$$

in which $p = \sqrt{kg/W} = \sqrt{g/\delta}$ is the characteristic constant. Attention is called to the factor δ representing in this equation the static deflection of the spring—a rather important parameter typical of this analysis.

Since the general solution of this equation is

$$x = A \cos pt + B \sin pt,$$

it follows that the motion of the natural vibration is a simple harmonic with the period

$$T = \frac{2\pi}{p} = 2\pi\sqrt{\frac{\delta}{g}}$$

This equation, though it is derived for the case shown in Fig. 1, holds good for many other types also; for instance, for the beam in Fig. 2a and for the cantilever in Fig. 2b, the factor δ being calculated as the static deflection in each individual case.

The masses of either the spring or of the girders have thus far been disregarded, but they can easily be introduced in this simple analysis by means of approximate, but sufficiently precise, formulae. For example, in the case shown in Fig. 1 we add one third of the weight ql of the spring to the weight W, and proceed otherwise in exactly the same way as before. Thus the natural frequency becomes

$$T = \frac{2\pi}{p} = 2\pi\sqrt{\frac{W + \frac{1}{3}ql}{g}}$$

In Fig. 2a the additional term (under the sign of the root) due to the effect of the weight of the beam on the period of natural vibration, will be $\frac{17}{35}ql$, and in Fig. 2b it will be $\frac{33}{140}ql$.

What is for us the most important generalisation of this formula is obtained for the case in which we have several loads (see Fig. 3); for this case, again, an approximate formula can be derived, giving the natural frequency period as a function of the *static* deflections—as calculated for the points of application of the various loads acting on the girder. Let these deflections be Y_1, Y_2, Y_3, etc., and let the corresponding loads be W_1, W_2, W_3, etc., then

$$T = \frac{2\pi}{p} = 2\pi\sqrt{\frac{W_1Y_1^2 + W_2Y_2^2 + W_3Y_3^2 + \ldots}{g(W_1Y_1 + W_2Y_2 + W_3Y_3 + \ldots)}}$$

The formula for T given earlier is obviously a particular case of this more general equation. On the other hand, while the first equation was supposed to be theoretically precise, the second formula is approximate only. The importance of this general formula depends on the fact that it reduces a vibration problem to the calculation of static deflections only.

Another aspect of this same problem deserving attention is the effect of damping. Had the phenomenon of vibration been as simple as presented in Figs. 1 to 3, the motion would have gone on indefinitely. This, however, as we well know, never occurs, as there are always some physical factors present which produce the gradual damping of free vibrations. These may either be air and water resistances, or internal friction of the vibrating material, or friction between sliding surfaces (i.e. Coulomb's *dry* friction), etc.

For small velocities the intensity of the damping force due to air and water resistances is frequently taken to be proportional to the velocity of the vibrat-

ing elements ("viscous damping"). Under other circumstances, however, the damping force may be proportional to the square of this velocity, or it may also be constant.

We shall begin the discussion with the first case as being the most obvious. The damping force will then be $\alpha\, dx/dt$, in which α is a constant. The basic differential equation will now include an additional term:—

$$W - \frac{W}{g}\frac{d^2x}{dt^2} - \alpha\frac{dx}{dt} = W + kx$$

or $$d^2x/dt^2 + 2Cdx/dt + p^2x = O$$

in which the ratio $C = \alpha g/2W$ is sometimes described as the "damping factor," and, as before $p = \sqrt{kg/W}$.

The general solution is

$$x = e^{-Ct}\,(A \sin \sqrt{p^2 - C^2}\; t + B \cos \sqrt{p^2 - C^2}\; t)$$

Let $p_1 = \sqrt{p^2 - C^2}$. We shall then find that the period is now equal to

$$T = \frac{2\pi}{p_1} = \frac{2\pi}{\sqrt{p^2 - C^2}}$$

Thus T is slightly shorter than it had been before, but nevertheless it is still a constant. On the other hand, due to the factor e^{-Ct}, the amplitude of damped vibrations gradually diminishes in time, as represented graphically in Fig. 4.

Another point of interest is this; it is almost obvious that as the damping effect increases, a limit must necessarily be reached when the movement will cease, or tend to cease. In fact, our equation shows that such conditions will be attained when $C = p$, because x will then be proportional to e^{-pt}, i.e. tend to zero. The value of C determined in this manner is referred to as the "critical damping factor," and denoted by the symbol C_c.

We can now draw certain general conclusions on free vibrations, which may later be used with advantage in investigating the nature of forced vibrations. For instance, in comparing the various equations appearing in the foregoing pages, it will be evident that the natural vibration period increases with the load and with the length of the vibrating element, but decreases with its sectional area and/or second moment.

These conclusions are essential in the study of forced vibrations, because the effect of these vibrations depends entirely on whether or not their period coincides (or tends to coincide) with the natural period. This point will be demonstrated in the following discussion.

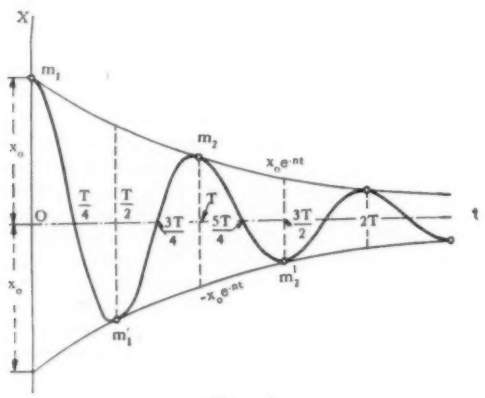


Fig. 4

Assume a periodic force $Q \sin mt$ acting vertically in Figs. 1, 2a and 2b. Then the differential equation will become

$$\frac{d^2x}{dt^2} + 2C\frac{dx}{dt} + p^2x = q \sin mt$$

where $q = gQ/W$

The general solution of this equation is obtained by adding to the general solution previously considered the particular solution

$$x = M \sin mt + N \cos mt$$

in which $N = -\dfrac{2qmC}{(p^2 - m^2)^2 + 4m^2C^2}$

and $M = \dfrac{q(p^2 - m^2)}{(p^2 - m^2)^2 + 4m^2C^2}$

Hence, the general solution is

$$x = e^{-Ct}(A \sin p_1t + B \cos p_1t) - \frac{2qmC}{(p^2 - m^2)^2 + 4m^2C^2} \cos mt + \frac{q(p^2 - m^2)}{(p^2 - m^2)^2 + 4m^2C^2} \sin mt$$

In examining this formula it will be observed that the first term on the right side yields the *damped natural vibration* which we have investigated earlier, whereas the two other terms are the *forced vibrations* superimposed over the former. These forced vibrations are proportional to the periodic force, Q, and have the same period $T_1 = 2\pi/m$. Their amplitude, A, depends on the relation between the periods T and T_1.

Let $N = -A \sin \alpha$ and $M = A \cos \alpha$. The sum of the two terms representing in our equation the forced vibrations, can then be transcribed in the form A (cos

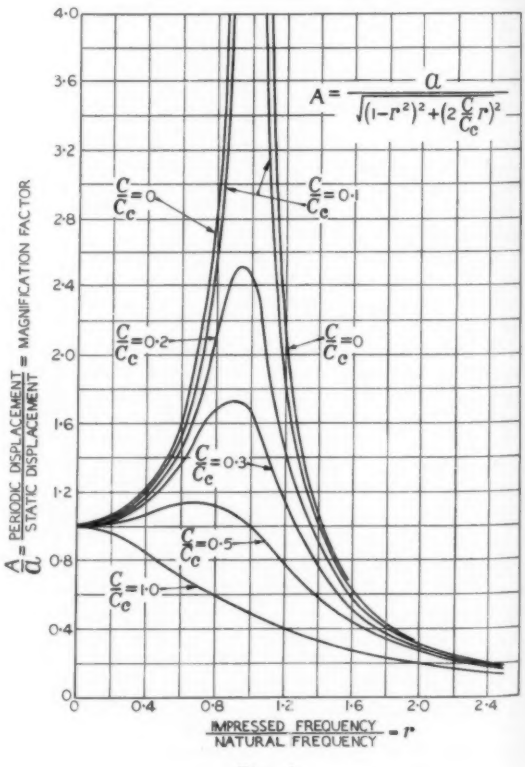


Fig. 5

$\alpha \sin mt - \sin \alpha \cos mt) = A \sin (mt - \alpha)$.

The amplitude $A = M^2 + N^2$ of these vibrations is thus found to be

$$A = \frac{q}{\sqrt{(p^2 - m^2)^2 + 4m^2C^2}}$$

Also α, viz. the difference in phase between the vibrations and the disturbing force Q, can be found from

$$\tan \alpha = \frac{2mC}{p^2 - m^2}$$

These equations confirm what was said earlier on forced vibrations.

Three cases can then occur:—

(a) $p > m$ = The period of natural vibration is less than that of the disturbing force. In this case α is positive and less than $\pi/2$.

(b) $p < m$ = The forced vibration is behind the disturbing force and $\alpha > \pi/2$.

(c) $p = m$ = This is the case of *resonance*. The value of tan α is now infinite, and $\alpha = \pi/2$. The vibrating element or vibrating system is in its middle position when the periodic force attains it maximum.

The amplitude, A, will next be considered. From $q = gQ/W$ and $p^2 = kg/W$, it follows that $qp^2 = Q/k = a$, where a is the deflection produced by the maximum pulsating force, had this force been applied statically. The equation for A can thus be presented in the form

$$A = \frac{a}{\sqrt{\left(1 - \frac{m^2}{p^2}\right)^2 + \left(\frac{2mC}{p^2}\right)^2}}$$

$$\text{or } A = \frac{a}{\sqrt{\left(1 - \frac{T^2}{T_1^2}\right)^2 + \left(2\frac{C}{C_2}\frac{T}{T_1}\right)^2}}$$

$$= \frac{a}{\sqrt{\left(1 - r^2\right)^2 + \left(2\frac{C}{C_2}r\right)^2}}$$

where

$T = \frac{2\pi}{p}$ is the period of natural vibration of the system;

$T_1 = \frac{2\pi}{m}$ is the period of the disturbing force;

$r = \frac{T}{T_1}$ is the ratio of the impressed frequency to the natural frequency;

C is the actual damping factor of the system;

C_c is the critical damping factor;

A is the amplitude of vibration displacement;

a is the static displacement from a static force equal to the maximum of the periodic force.

This well-known formula is used by Mr. Samuel Judd* in preparing the diagram reproduced in Fig. 5.

Inspection of this diagram will help in deriving various useful conclusions pertinent to forced vibrations; for instance, if the disturbing force has a very large period, A will approach a, i.e. dynamic and static deflections will tend to equalise; which means that as the period of the imposed force tends to infinity, its dynamic effect diminishes and its action becomes similar to that of a force whose action is static. On the other hand, should T tend to decrease, that is to say, should the frequency of the external force rise, then the denominator in our equation would tend to infinity, and therefore, the amplitude of the enforced vibration would gradually diminish (as shown in the diagram).

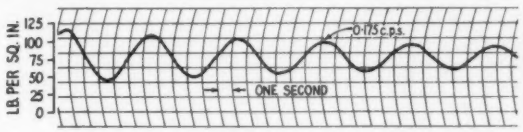


Fig. 6

Thus very short or extremely long enforced vibration periods are both relatively harmless, but what may under circumstances become indeed dangerous, is an intermediate value of this period, viz., that value thereof which approaches the period, T, of the natural vibrations. In fact, for $T_1 = T$ the denominator in the equation is equal to zero, and A is therefore infinitely large ("resonance"). These are, consequently, the conditions when even a very small external periodic force may produce rather serious vibrations.

We shall next consider the effect of various damping factors. In this case also, the diagram Fig. 5 furnishes useful information, particularly in regard to the efficacy of damping if used as a means for protecting a structure against undesirable vibrations. Actually, the diagram shows that damping yields beneficial results for frequencies either about 40 per cent. below, or about 40 per cent. above the normal frequency of the system; but, for the remainder of the frequencies ratios, it has little effect on the enforced amplitude, and other means for reducing vibrations must consequently be resorted to, when the frequency of the periodic external force tends to approach the natural frequency of the structure.

The main conclusion which this diagram and all the foregoing discussion are supposed to substantiate and explain, is that in so far as vibrations are concerned, the designer of the power house will endeavour to produce a structure, the natural frequency of which does not coincide with any of the frequencies of the periodic forces it may eventually be called upon to resist.

We may now ask, what are these forces? Apart from vibrations due to natural causes—such as wind and earthquake, which, strictly speaking, do not belong to the scope of this discussion, as having no specific bearing on the problem of hydro-electric stations as such—Mr. S. Judd quotes (*loc. cit.*) five different types of vibrations, all of them caused by man-made forces, which may eventually affect a power house belonging to a hydro-electric power station; namely as follows:—

1. *Periodic pressure surges due to water hammer.* These surges occur in penstocks and may be produced by rhythmic wicket-gate movements, for instance, as in Fig. 6 (Tracy pumping plant).

The frequency of these surges is

$$F = \frac{V}{4L}$$

where V is the velocity of water-hammer waves and L the length of the penstock. In the case shown in Fig. 6 the frequency is 0·175 cycles per sec. It is believed

* See: Samuel Judd, "Vibration in Hydro-electric Power Plants," *Proc. Am. Soc. Civ. Eng.*, Separate No. 637, March, 1955. Much of the following information, as well as Figs. 5 to 7 are abstracted from this valuable paper.

that hydraulic resonance will rarely occur due to these surges, because they will be damped out rapidly by wave reflection.

2. *Draft-tube surges.* Though the phenomena causing draft-tube surges are not yet completely understood, they are, nevertheless, commonly assumed to be the result of the air or vapour, which accumulates in

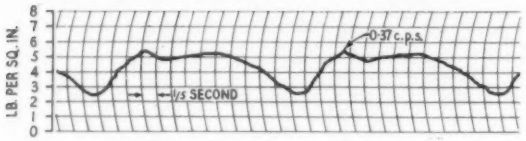


Fig. 7

the upper part of the tube, just below the axis of the runner. They are a strong source of low-frequency vibrations, because a fluctuation in the draft-tube vacuum is immediately reflected in a corresponding fluctuation in the effective head and in the discharge of the turbine. Such fluctuations create water-hammer effects in the penstock and are the source of power swings, the magnitude of which depends on the relation between the frequency of the surges in the penstock and the natural frequency of the generator. Mr. Judd illustrates (*ibid.*) this type of surge by means of Fig. 7, which reproduces the results of measurements made at the Parker power plant.

In this case, the observed frequency was 0·37 cycles per sec. Speaking more generally, it is believed that the frequency of the draft-tube surges and power swings is roughly correlated with the speed of the turbine, as expressd by the formula

$$F=\frac{N}{216}$$

in which N is the speed of the turbine in revolutions per minute (if F is given in numbers of cycles per sec.).

3. *Vibrations due to improper relations between turbine design factors.* Such factors are:— (a) speed of rotation, (b) number of guide vanes, (c) number of runner buckets, (d) length of spiral case, and (e) velocity of water-hammer waves in the penstock. The same author mentions a case (reported by Den Hartog*) in which serious vibrations were traced to an unfortunate combination of the quoted factors. In fact, in this case, the pressure impulses caused by the runner-buckets passing in front of the guide vanes were in phase, and the pressure waves thus produced caused forced vibrations in the penstock.

4. *Unbalanced rotating parts.* Statical balancing of the turbine runner is an important operation, usually performed in the shop. Messrs. A. L. German, A. S. Punger, V. A. Vakhrameeff and I. B. Okuloff describe† the methods used in carrying out this particular operation in Russian factories, in charge of mass production of small and medium hydraulic turbines.

Two methods are used, the axis of the tested runner being kept horizontal in one case, and vertical in the other. The first solution seems to be cheaper, but the second yields more accurate results. To use the first method, the spindle of the runner must first be extended by means of additional pieces fixed at its two extremities. These temporary additions are made of a particularly high grade of hard steel and are in line and strictly concentric with the permanent spindle.

The runner is then placed on two parallel, and precisely horizontal, rails. If the centre of gravity of the runner falls exactly on its geometrical axis of rotation (as it should theoretically be) the runner will remain steady in any position. This, however, is seldom, if ever, the case. What usually occurs is that, owing to the unavoidable inaccuracies of manufacture, there is present a slight eccentricity, i.e. the centre of gravity of the runner is located at some small distance from its true axis of rotation; hence, the runner will roll on the horizontal rails, until its centre of gravity gets in its lowermost position.

The aim of the operation is to remove this eccentricity, viz. to make such adjustments which are necessary to ensure that the centre of gravity will be exactly on the axis of rotation. This is done by adding to, or removing from, the rim of the runner some small amounts of metal. The object of this test is to ascertain how much material—and in what particular spot—should be thus added or removed.

With reference to Fig. 8, abstracted from their publication, the authors quoted recommend the following procedure.

The periphery of the rim is divided into eight equal parts (as shown in the upper diagram) and the runner is placed, *seriatim*, in each position thus indicated. Trial loads are then attached on either side of the runner, and the minimum loads required to cause it to roll (either to the left or to the right) are recorded.

The figures thus obtained are then plotted, as shown in the lower diagram, against the corresponding sections of the developed periphery of the runner. We can then draw two curves: the full curve for the incipient movement to the right and the dotted curve for such movement to the left.

Attention is called to the fact that the difference between the ordinates of the curves is consequent on the effect of rolling friction, which opposes the movement in either direction. The minimum points on the curves (in our case points 5) are symptomatic of the lowermost position of the centre of gravity. This is, therefore, the spot where metal should be removed. Alternatively, the same result can be arrived at by adding weight in the diametrically opposite points (points 1 in the drawing).

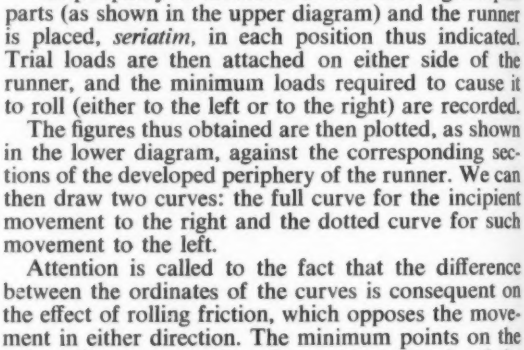


Fig. 8

* Professor J. P. Den Hartog, "Mechanical Vibrations."
† "Technology of production of small and medium hydraulic turbines," Moscow, 1954 (in Russian).

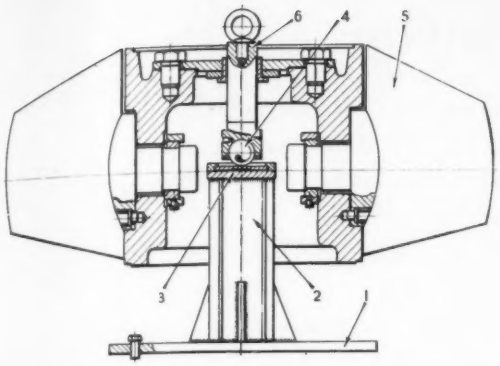


Fig. 9

The weight to be thus either removed, or added, is the average between the maximum and the minimum recorded weights. Thus, for right-handed movement

$$P=\frac{P_{max}+P_{min}}{2}$$

and also, for left-handed movement

$$Q=\frac{Q_{max}+Q_{min}}{2}$$

In our case (see figures on the diagram)

$$P=\frac{30+(-20)}{2}=5 \text{ kg.}$$

$$Q=\frac{19+(-28{\cdot}8)}{2}=-4{\cdot}9 \text{ kg.}$$

Theoretically, both figures should be equal. In practice, however, we take the average of the two.

The second method—that in which the axis of the runner is vertical, or almost so, during the test—is shown in Fig. 9.

In this case, the spindle of the runner is removed entirely, and is replaced by a temporary shaft, carrying a hard steel ball. The diameter of this ball is calculated to be capable of supporting the entire weight of the runner. The arrangement is then placed on a steel stanchion topped with a strictly horizontal plate.

Should there be no eccentricity, the runner mounted in this manner would remain standing in a strictly vertical position. There again, however, this will seldom happen, but the weight and location of the additions required to balance the runner will be easily determined by attaching temporary loads in various points of its rim, until it remains standing vertical.

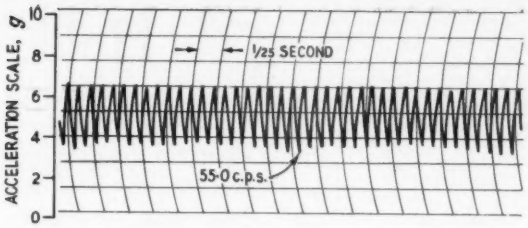


Fig. 10

It should be realised that, apart from the two methods described, many other solutions can be (and are) used by various turbine makers. The only object of describing these two methods here is to acquaint the reader with the concept of a statically balanced runner, for the principle is rather an important consideration in the theory of turbine-house vibrations. In fact, although the rotor of the generator is also tested and balanced (in the same manner as the runner of the turbine) practice shows that when both of them are bolted together, and begin rotating as a unit, additional disturbing forces caused by centrifugal effects are imposed on this unit. Dynamic balancing of the unit is then performed at normal speed by attaching weights to the rotor of the generator, but if it is not fully effective vibrations will be set up, the frequency of which is determined by the number of revolutions of the unit, viz.

$$F=\frac{N}{60}$$

where F and N have the same meaning as before.

5. *Vibrations of turbine-runner blades.* These vibrations have been observed, particularly on runners of large diameters. They are presumably due to vortex formation behind the trailing edges of the blades, and may be reduced by thinning these edges (Parker power plant) or by lowering the downstream water level (Keswick power plant). The observed ranges of frequencies (as measured at these two stations) were 55 to 65 cycles per sec in one case (see Fig. 10), and 150 to 170 cycles per sec. in the other case.

(To be continued)

Civil Engineering . . . A Creative Career

A new four-page leaflet describing ways of entering the civil-engineering profession has been produced by the Institution of Civil Engineers, Great George Street, Westminster, for issue to schools and at exhibitions on civil engineering. Entitled "Civil Engineering . . . A creative career," it has been prepared with the idea that very few young men considering the professions open to them have much idea of the opportunities throughout the world which are increasingly open to civil engineers, and that this is largely because so little effort has hitherto been expended in informing them. The cover photograph of the leaflet is in colour by the well-known industrial photographer Adolph Morath. The centre pages give a general outline of the profession and a chart shows four ways of reaching the objective of becoming a "Chartered Civil Engineer." The rear cover is a composite photograph showing some British achievements in civil engineering at home and abroad.

VOEST. A handsomely produced brochure received from Vereinigte Österreichische Eisen-und Stahlwerke A.G. of Lintz, Austria, gives an account of this firm's extensive activities, of which the manufacture of water-power equipment forms an important part. This equipment comprises pipelines, Y pieces, valves of all kinds, sluice gates, turbines, transmission towers, etc. The brochure is impressively illustrated in colour. A further publication isued by VÖEST, also in English, deals with the production of LD steel, of which the firm have produced over one million metric tons since 1953. This high-grade steel is now being handled in 30 ton (metric) converters.

Hells Canyon

A short account is given of the objective of this scheme, which involves the development of a 100 mile reach of the Snake River, and about which there has been considerable controversy in the United States

By IAN B. MACKINTOSH, M.A., A.M.I.C.E., A.M.A.S.C.E.

THERE has been a vigorous political controversy over the Hells Canyon Project between public power interests on the one side, and private power interests on the other. The two parties proposed to develop the 100-mile reach of river passing through Hells Canyon in quite different ways. The Canyon lies on the border of the States of Idaho and Oregon in the Pacific North West. In August 1955 the United States Federal Power Commission granted a licence to Idaho Power Company, an investor-owned corporation, to develop the site for hydro-electric power by building three dams and construction was started in the following November. In 1952 the House Committee on Interior and Insular Affairs held hearings in Washington when the Secretary of the Interior proposed a federal scheme for the development of Hells Canyon by a single high dam. At that hearing testimony was given on behalf of the private scheme for three dams. At the Federal Power Commission hearings held 1954-55 objection was made to the proposed licence on the basis of the high dam scheme proposed earlier by the Department of the Interior, although the Department itself did not oppose the licence. Earlier this year a bill to adopt the federal scheme, notwithstanding the fact that the private scheme was under way, was rejected by the U.S. Senate.

There is a conflict between high dams and a series of low dams on the Missouri River and elsewhere, on account of the flooding of valuable agricultural land by the reservoir of a high dam. This is not a factor at all at Hells Canyon where the land is quite barren, although the issue is indeed one of a high dam and low ones. It is not a problem that can be generalised; each individual site must be considered on its own merits. The physical situation of Hells Canyon and the relation of the river to the region are rather unusual.

The location of Hells Canyon is shown in Fig. 1, which also shows existing major hydro-electric plants and those authorised by Congress for future development. The Snake River is the largest tributary of the Columbia River into which it discharges at Pasco, Washington, some 350 miles from the Pacific Ocean. Hells Canyon, the deepest canyon in North America, is on the main stem of the Snake 330 miles above Pasco. Two major branches of the Snake join the river below Hells Canyon, the Salmon River and the Clearwater River.

Data for the three low dams and the high dam are as follows:

Name	Height (ft.)	Output (kW)	Reservoir Actice Storage Capacity (acre ft.)	Type
Brownlee	395	360,400	1,000,000	Rockfill
Oxbow	205	151,000	6,200	Rockfill
Hells Canyon ...	320	272,000	11,200	Rockfill
High Hells Canyon	742	800,000	3,800,000	Gravity Arch

Costs

There is a wide difference in the estimated costs of the two schemes as proposed; $133 million for the three low dams and $390 million for the high dam. Yet the schemes achieve essentially the same objects despite certain downstream benefits claimed for the high dam; but as will be seen later these are theoretical and may not be realised in practice. All three of the low dams would be similar in type of structure, namely the Nantahala type of rockfill dam with a sloping upstream impervious earth zone weighted down by a heavy rock facing for protection. Utilising as it does the materials available at the site this type of dam proves to be very much more economical than concrete dams of the same height. The high dam proposed was a concrete gravity arch dam of the same type and only a little higher than Hoover dam, Shasta dam and the proposed Oroville dam in California. If the high dam had been proposed in the Nantahala type it would have been more than twice as high as any previous dam of the same type, the highest of which in existence is the Kenney dam, 324 ft. high, in British Columbia. The proposed high Aswan dam is of the same type and is planned to be 360 ft. high above the stream bed. Rolled earthfill dams are rather higher; for example, Anderson Ranch dam, Idaho, is 456 ft. high and the proposed Swift dam for the Pacific Power & Light Co., on the Lewis River, Washington, some 600 ft. high above bed rock and on which construction is expected to commence shortly. In addition to the Company's own consulting engineers for the three low dams an independent engineering advisory board was employed which included two of the world's leading dam engineers, Mr. I. C. Steele, formerly Chief Engineer of Pacific Gas and Electric Company of California and Mr. J. P. Growden, formerly Chief Hydraulic Engineer for the Aluminum Company of America. A similar advisory board for the high Aswan dam included Steele, Terzaghi, Straub, Harza, Pruess and Coyne. However, the Nantahala type of dam has not found favour with the advisers of some prominent public authorities.

The cross section of Brownlee dam is shown in Fig. 3, and a plan and a section of the development are given in Figs. 2 and 4.

Storage

It is claimed that the high dam would be justified by the value of the additional storage provided in the reservoir, 3,800,000 acre ft., compared with 1,000,000 acre ft. for the three low dams. The value of this additional storage is rather theoretical since it is mainly based on its value to downstream plants in times of prolonged water shortage. The Snake is already a

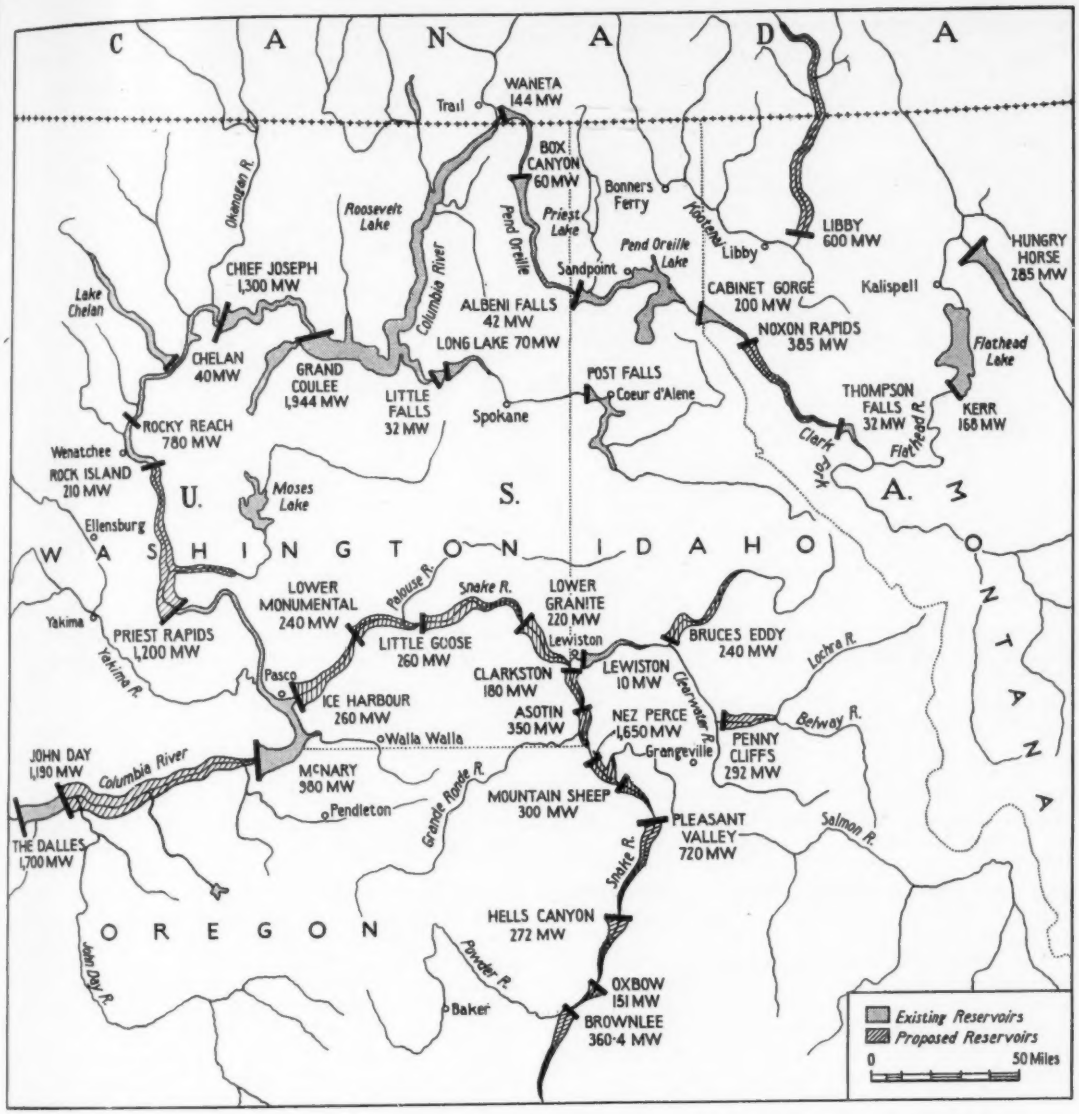


Fig. 1. Map of the Columbia River catchment showing locations of existing and projected dams

highly regulated stream when it enters Hells Canyon. During the period of record the total annual runoff has varied from some 8 million acre ft. to 17 million acre ft., with an average of 12 million acre ft. The total upstream storage of 8 million acre ft. in nine reservoirs built by the Bureau of Reclamation and the U.S. Army Engineers principally for irrigation provides an unusually high degree of regulation. An important part of the flow of the river, moreover, comes from underground sources near Thousand Springs, Idaho, and this supply is nearly constant throughout the year. In the great majority of years 1½ million acre ft. of storage is sufficient to regulate the steam fully. and the storage provided by the three low dams will provide two-thirds of this amount. The remaining 500,000 acre feet are already contemplated by two additional dams immediately below Hells Canyon, applications for which are pending in the name of the North West Power Company before the Federal Power Commission. In addition upstream reservoir sites on the Snake and its tributaries needed both for local irrigation and flood control will provide additional storage of several million acre feet. This future storage with the 8 million acre feet of storage already existing, will aggregate more than the total average annual flow of the river, thus having a direct effect upon the availability of water for storage downstream at Hells Canyon.

Based upon a 20 year study of past river flows, adjusted for river depletion from future upstream irrigation development it appears that even under present-day irrigation conditions, there will be only four years out of twenty when 3,800,000 acre ft. would be available during the storage season for the high

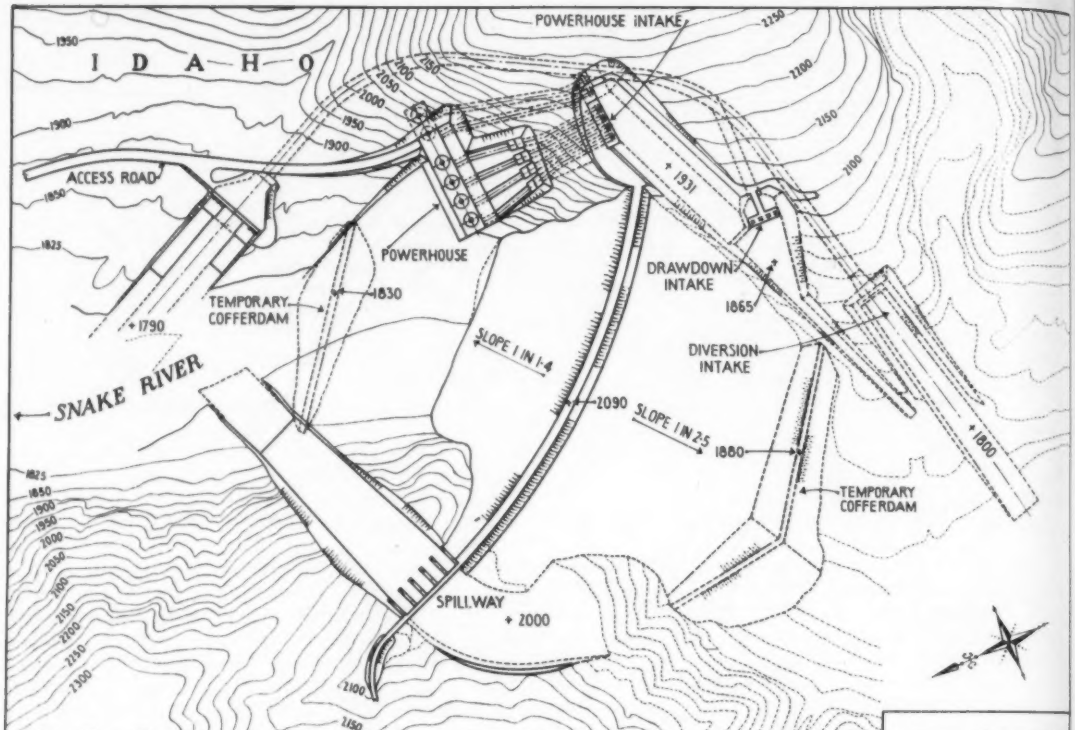


Fig. 2. General plan of Brownlee development

dam. As future upstream irrigation increases this amount of water for storage at Hells Canyon will further decrease.

The 1,000,000 acre feet of storage in the Brownlee dam will be utilised each year for power and flood-control requirements. The additional 2,800,000 acre ft. of storage which the higher dam would provide would be used for cyclic storage and would be drawn upon only once on the average in twenty years.

The North West Power Pool

To appreciate the use of this cyclic storage in a time of great water shortage it is necessary first to understand the operation of the North West Power Pool, as Hells Canyon is a unit in the development of the hydro-electric resources of the whole Columbia Basin. On the Columbia River there are large flood flows which cannot be utilised. The active storage at Grand Coulee dam, 5 million acre ft., is insignificant compared with the average run-off above the dam of 77 million acre ft; the natural run off varies from extremes of 20,000 to 637,000 cusecs. Moreover, during a flood the plants cannot develop full power owing to high tailwater level. To help to firm up the overall output of all Columbia Basin plants, upstream storage is used and illustrations of how this is done are given by referring to the Albeni Falls and Kerr dam plants.

Albeni Falls Dam is a low dam, only 100 ft. high, which raises the level of a large natural lake, thereby providing an active storage of 1,153,000 acre ft. This can be used every spring by allowing the reservoir to

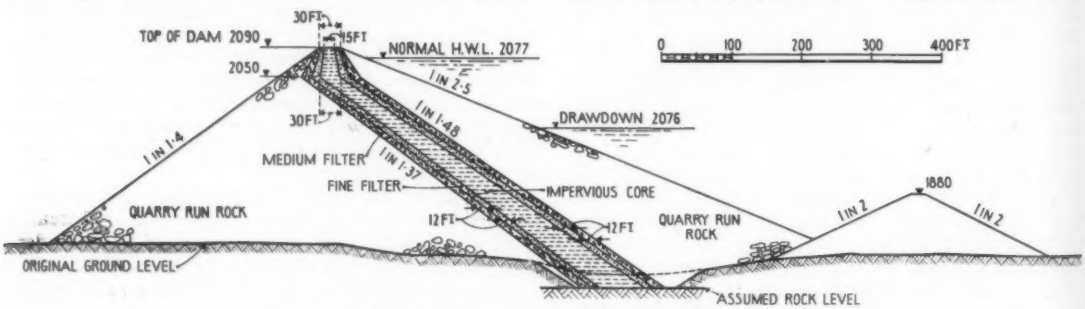


Fig. 3. Cross section through Brownlee dam

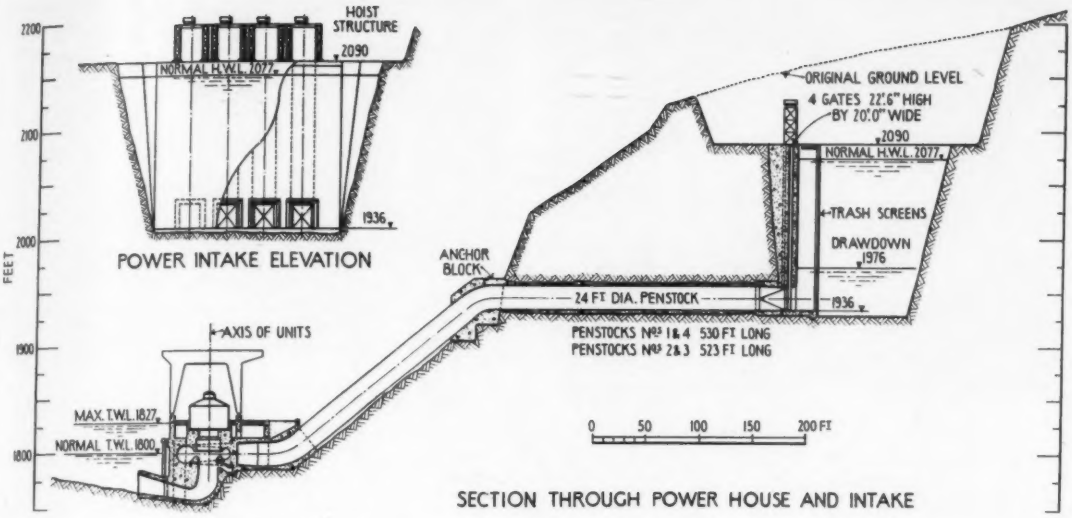


Fig. 4. Section through Brownlee power house and intake

fill and then releasing the water the following winter. This is of great value to eight downstream plants including Grand Coulee and Chief Joseph. The power plant at Albeni Falls has an average operating head of only 22 ft., and if it had been eliminated altogether the dam would still have paid off handsomely in terms of its downstream benefits.

A different type of operation is carried on at Kerr Dam, owned by Montana Power Company. The plant has a capacity of 180,000 kW at a head of some 200 ft., and an available storage of 1½ million acre ft. with a small draw down, as it controls the outflow from a large natural lake. The operation of the reservoir is illustrated in Fig. 5. During the flood run-off, due to snow melt in April-June, the plant is operated at a high capacity on base load and at full capacity during peak periods, while the reservoir nevertheless fills up. Later, in July-September, when Columbia flows are normal with no tailwater limitations at the plants, the reservoir is kept at a high elevation, using the inflow for peak generation. During the low-flow period from October to March storage is drawn upon, the power being used for peak generation as before. In this way the Montana Power Company is drawing on surplus energy from run-of-river plants in the North West Power Pool and repaying it back with power when the run-of-river plants are short of water, as well as releasing additional water to the ten plants downstream.

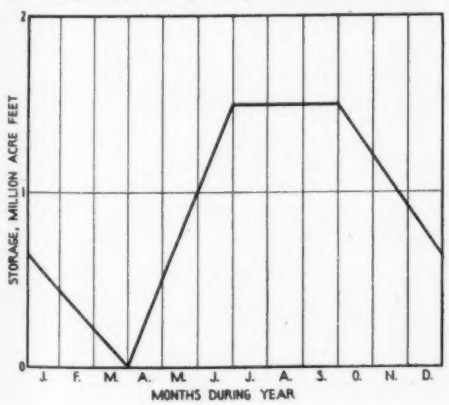


Fig. 5. Annual reservoir operation of Kerr dam

The two examples considered are ones where, on the one hand, at-site generation is of little importance compared with the provision of storage; and on the other hand where a development justified entirely as a generation plant gives gratuitously to its neighbours by operating its reservoir for their benefit.

The low dams at Hells Canyon are capable of being operated and paid for in just the same way as Kerr. The additional 2·8 million acre ft. that would be provided by a high dam could not be used in normal years, but would only be used in the so-called 'three-year dry cycle' which occurs roughly every twenty years. One study, which assumes the existence of plants downstream and additional units at existing plants, shows that the worst period of drought during the 80-year period of record, the 3,800,000 acre ft. of storage could in theory be used to increase the firm output of the downstream plants, together with Hells Canyon, from 3,400,000 kW to 4,216,000 kW, a net gain of 816,000 kW. This type of operation is shown in Fig. 6. Firm output is weekly average generation, enough pondage being available only for daily and weekly regulation on the Columbia. During this very dry period firm power at Hells Canyon itself would have to be cut to 60,000 kW at certain times.

It is very difficult to evaluate the firming up of hydro-electric power during an extended period of water shortage attributable to a particular investment because there are so many variables. In the case considered above it would be necessary to find what firming up would result by the use of 1,000,000 acre ft. of storage and this would have to be deducted from 816,000 kW. Then less severe cases of dry cycles occurring more frequently would be considered with a corresponding reduced net firming up resulting.

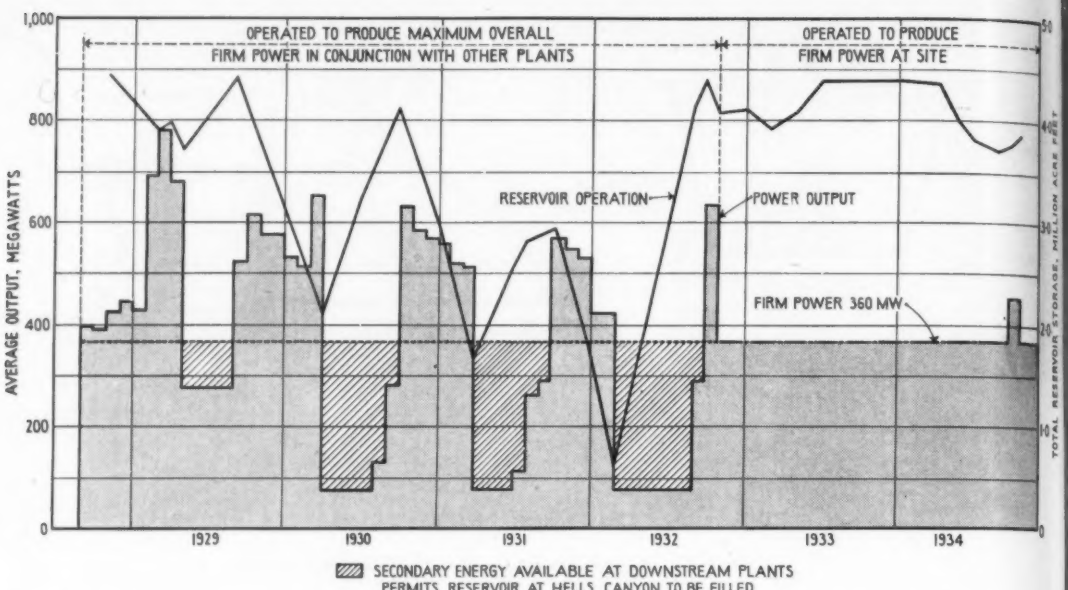


Fig. 6. Hells Canyon potential power output and reservoir operation during critical period of stream flow

The annual fixed charges on hydro-electric developments in the United States are approximately 6% for public development and 12% for development by a private power company. The difference is accounted for partly by Federal and local taxes, and partly by the different interest rates chargeable due to the freedom from personal income tax on government bonds. The cost of electric power from a privately-owned modern high efficiency steam plant is approximately, at 1955 prices, $23 annually per kW of generating capacity plus 3·25 mills per kW hr. (1 mill = 1/1000th of $1). Federal Power Commission engineers, even assuming that the three dam plan would cost $195 million, found that the incremental power from the one dam project would cost $8,189,000 and have a value of only $5,221,000 regardless of the additional capital expenditure in adding downstream generators and the provision of transmission lines, together with transmission losses, when the alternative steam power plants would be located at the load centres on the coast.

In terms of flood control the incremental 2,800,000 acre ft. of storage would have very little value, since operating the reservoir for power purposes would make this storage available so very rarely. The major flood damage occurs on the lower Columbia River and during the great 1948 flood only 5% of the total flow at the Dalles on the peak day had come out of the Hells Canyon reach of the Snake River. During this flood the flow in Hells Canyon was only 50,000 c.f.s. compared with 177,000 c.f.s. in the Clearwater River and 100,000 c.f.s. in the Salmon River, both of which enter the Snake River below Hells Canyon. It is these two rivers which need the flood control dams. Brownlee dam will have low level discharge gates capable of emptying the reservoir at the rate of 65,000 c.f.s. as required by the Army's main flood control plan. Brownlee, so operated, will provide substantially the same benefits as the high dam.

In November 1955 a contract for $87 million was signed with Morrison-Knudsen Company for the con-

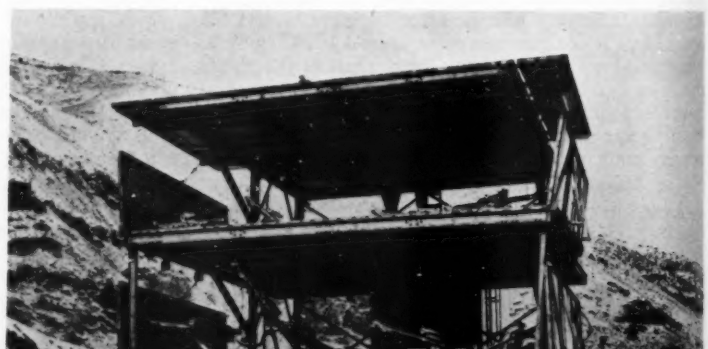


Fig. 7. Drilling jumbo for 42 ft. diameter Brownlee diversion tunnel

Fig. 8. Artist's impression of Brownlee development

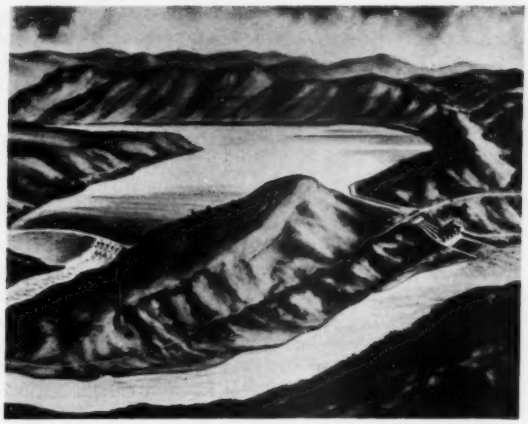


Fig. 9. Artist's impression of Oxbow development

struction of Brownlee and Oxbow dams and work started immediately at the site. The completed developments at Brownlee and Oxbow are illustrated in Figs. 8 and 9. The first major item of construction was the driving of Brownlee's big diversion tunnel in the Idaho abutment and the deep approach cuts to its portal, and this was all completed in July 1956. The tunnel is 42 ft. diameter and 2,600 ft. long, the huge jumbo used being equipped with 14 two-man drills on three decks, as shown in Fig. 7. This was switched from one heading to the other for drilling, and mucking out was done with a shovel loading into Euclid trucks.

A temporary fill was made in the river bed at the dam site from which samples of the foundation rock were taken by core drilling. The 5 million cu. yd. rockfill dam will be 395 ft. high and 1,320 ft. at crest.

A batching and aggregate processing plant will be set up at the Oxbow development, whose construction is to follow closely that of Brownlee. Aggregate material will come from a gravel deposit in the river. The 125,000 cu. yards of concrete required for the Brownlee development will be transported from Oxbrow in ready-mix trucks.

Acknowledgements

The author's thanks are due to Idaho Power Company for their co-operation in supplying information for this article and to Morrison-Knudsen Company for permission to reproduce Figs. 7, 8 and 9 from *The Em Kayan*.

Scottish Electrical Training Scheme

The electrical engineering industry in Scotland has launched a co-operative training scheme to encourage the recruitment of suitable young men to the Scottish electrical industry. It is proposed to train graduates in electrical engineering and those holding equivalent diplomas for the two years necessary to qualify for Graduateship of the Institution of Electrical Engineers; it will also provide vacational training. Training will be carried on in the works and establishments of the member firms, and will provide one year's basic training followed by a second year in which the trainee will be sponsored by one of the member firms with a view to ultimate permanent appointment.

A company is being formed, "Scottish Electrical Training Scheme Ltd.", sponsored by: The Belmos Co. Ltd., Bellshill; Bruce Peebles & Co. Ltd., Edinburgh; The Harland Engineering Co. Ltd., Alloa; Honeywell-Brown Ltd., Motherwell; North of Scotland Hydro-Electric Board, Edinburgh; Scottish Cables Ltd., Renfrew; South of Scotland Electricity Board, Glasgow. Offices have been taken at 127 St. Vincent Street, Glasgow, C.2., and an Organising Secretary, Mr. J. E. C. McCandlish, has been appointed. The Organising Secretary has already visited most of the Universities and Colleges and spoken to young men who have expressed an interest in the possibility of carrying out their practical training with the scheme.

"On the Development of Water Power." Gilbert Gilkes & Gordon Ltd., Kendal, who celebrated their centenary last year, have published successive editions of a handbook under the foregoing title since 1896, and the Centenary Edition, just published, is the thirteenth the firm has produced. It is directed more to the potential user of small and medium-sized water turbines than to the specialist hydro-electric engineer, as the space is devoted mainly to advice on the preliminary assessment of the power potentialities of a site and on the choice of appropriate plant. The handbook is excellently produced and illustrated, and the text is admirably written.

Joint-Sealing Compounds. An excellently produced booklet has been published by Expandite Limited, Chase Road, London, N.W.10, under the self-explanatory title "For Joints that Move." The variety of sealing compounds and devices that this firm produces is truly amazing, and the hydro-electric engineer should be able to find the answer to many of his sealing problems in its pages.

Ransomes & Rapier Limited have issued three leaflets dealing respectively with their new 414 four-purpose equipment which functions as skimmer, shovel, dragshovel and crane (Publication No. F/23), their 5T and 7T tilting concrete mixers (Publication No. 1/483), and their batch-weighing equipment for non-tilting mixers (Publication No. J/11).

Progress on St. Lawrence Seaway Scheme

This project has reached the half-way mark and the constructional work is on schedule

By H. G. COCHRANE, M.E.I.C.

At the end of the 1956 construction season, with rather more than half the allotted time elapsed, work on the St. Lawrence Seaway and Power Project is "on schedule." This was the opinion expressed by officials of the four "Authorities," one for power and one for navigation in each of the nations concerned.

Some elements are well ahead of schedule; others are slightly behind, but for these there is still time to catch up. The Long Sault dam is being built on a very tight schedule, and continuation of the good progress to date is a "must" if the first generators are to be "on line" by September 1958. Progress on two of the locks has been slow, but here delays can be overcome by longer or double shifts, or by the winter placing of concrete.

Right from the start the project has been plagued by shortages of skilled labour, particularly on the American side, due to a record construction volume in both countries. Cement was sometimes on a hand-to-mouth delivery basis, and there was also a shortage of steel during and after the U.S. steel strike last summer, particularly in plate and structurals. This may yet retard bridge construction and the delivery of many of the smaller steel items for which orders were not placed early. Greater defence effort due to unsettled Middle-East affairs could still upset the timetable.

At the peak of the 1956 construction season in late summer nearly 14,000 men were employed on site. During the winter the force will dwindle to around half that figure as dredges close down and as the concrete work on most of the structures on the American side stops for the winter. Next summer peak employment will exceed that for 1956.

Close co-ordination between all four authorities and the contractors concerned has been imperative. Exact timing for changing the course of the river from one channel to another must be carefully followed, due to the interdependence of the various operations and the effect a delay by one may have on others.

Canadian and American Practices Differ

Construction industry ideas and practices differ on either side of the international boundary. The Canadians, accustomed for years to placing concrete in the coldest winter weather, are geared to continuous pouring operations around the calendar. A vigorous effort is currently being sponsored by the Canadian Construction Association, directed towards creating maximum winter employment so as to reduce seasonal fluctuations. This effort is supported by all Government departments concerned with public works. Canadian engineers favour pouring 30 to 40 ft. continuous lifts of concrete, and placing on most of the Canadian structures will continue steadily throughout the winter.

United States engineers, on the other hand, feel it is not economical to heat the aggregates and water and to protect the concrete during the winter frost. They prefer to install bigger mixers and to use more force and equipment during the mild weather, and then close everything down during the winter. They pour concrete in maximum lifts of 5 ft.

Increased Costs

Original estimates for the cost of the project, in round figures, were set at about $200 million for the Canadian navigation channels, five locks and bridge alterations; $105 million for the American navigation channels and two locks, while power facilities were estimated at some $650 million, to be shared equally between the New York Power Authority and the Ontario Hydro. Meantime some additional dredging and two more bridges have been authorised. It is yet too early to assess what the overall cost will be, but the final bill will most likely be higher than the estimated $955 million. There are several reasons for this. Many early contracts were under-bid due to severe competition and the publicity value attached to the work. This brought substantial losses to some contractors and defaults by two firms, resulting in further claims and re-negotiation. Excavation was difficult and costly in the tough glacial till, which proved more solid than was at first indicated. Elsewhere, slippery marine clay and shifting gumbo caused slides and made digging slow and expensive. Nobody is likely to make any big profits. Moreover, the ever-upward trend of the prices index tips the odds against any saving.

Power Structures Get the Spotlight

In contrast to the work on navigation channels, much of it underwater, structures on the power end of the undertaking were the most conspicuous, the International Powerhouse, as a whole, having reached between 40 and 50 per cent. of completion by the beginning of the present year.

Progress on the two halves had been about neck and neck early last summer, but by the end of 1956 the Americans had forged well ahead. The American half was close to 50% completed by mid-December with 450,000 yards placed, while the Canadian half was about 40% complete. The Canadian half will catch up during the winter while work on the American half is shut down. The American half will cost close to $80 million, including the six generators, while Canada hopes to equip its half for $73 million. The generators are all of the open type, without superstructure.

All 16 of the American draft tubes were partly built, with eight completed. Five Canadian draft tubes were done and two more had been started. Embedded

parts of the turbines were being delivered and the installation of the liners and discharge rings was in progress.

The first stage of the Long Sault dam, being built by NYSPA, was completed except for rollways, with gates and one gantry in place. At mid-December about 20% of the flow of the river had been diverted down the channel south of Long Sault Island and through the temporary dam openings between piers. About Christmas, when a temporary earth plug was blasted out of "Cut F" upstream, the 80% flow previously passing down Long Sault rapids was gradually diverted through dam openings, drying up the Long Sault rapids below a rock fill now under construction.

On the Iroquois control dam at Lake Ontario, some 25 miles above the powerhouse, the first stage was completed except for the rollways. Almost the entire river was flowing through it as the cofferdam cells for the second stage were rapidly being built across the Canadian side of the river.

Other Work by Power Entities

The diversion structure for the temporary canal on the Canadian side was completed by Ontario Hydro and the diversion channel dug to 14 ft. depth. When a duplicate Canadian channel is required for increased canal traffic, the channel will be deepened to 27 ft. and the structure will become part of a future lock to accommodate half the 90 ft. lift in the International Rapids section, with a second lock to be built below Cornwall by Canada's Seaway Authority.

Dredging for channel improvement and increased flow in the International Rapids and The Thousand-Island sections has been proceeding steadily and the work has passed the halfway mark, mostly on schedule. This work is being done by the Power Authorities.

Clearing was about 25% done on Long Sault and Delaney Islands and on the Canadian side. This work will be speeded up during winter months. Tracklaying on the 40 miles of C.N.R. double-track main line has been completed and 75% ballasted, and much of the necessary road diversion work has been done.

American Channel and Locks

Dredging and excavation of the Long Sault channel across the islands at the upstream end opposite Massena is 95% completed and excavation and dredging along the overland mainland canal is about almost half finished. Excavation for the two American locks and approaches is two-thirds completed.

Canadian Navigation Channels

Progress on navigation channels and five locks on the Canadian side by the Canadian Seaway Authority in 1956 was marked by completion of several contracts and a change in emphasis from excavation to the building of structures. All contracts had been awarded excepting for dredging of approach channels to the Iroquois Lock and for two dredging contracts for the Welland Canal.

At the upper and lower Beauharnois Locks, started early last summer, three contractors were actively excavating the tough sandstone rock at a combined rate of 10,000 yards daily. For the Iroquois Lock, the first to be started, early completion was a necessary factor in the co-ordinated development of the river by both the Seaway and Power entities. A large and deep excavation across Iroquois Point had to be done first. More than 3½ million yards had been excavated and over 100,000 yards of concrete placed. Concrete placing will continue during the winter.

Additional Work on Channels

A controversy between the two governments lasting several months has finally been resolved, concerning the dredging of a channel on the north side of Cornwall Island, required for restoring the natural balance of flow under the Boundary Water Treaty. This dredging will now be carried out, with each Seaway Authority sharing the cost, some $34 million, less $12 million contributed by the two power authorities.

The United States Corps of Engineers will soon launch a huge channel dredging and deepening job on the Great Lakes, involving some 44 million cu. yards of dredging and excavation, at a cost of $150 million. The work, which may tax the dredging industry's capacity to the limit, was authorised by Congress in the spring of 1956. Most of it is on the St. Mary River and at the Soo Locks, in the St. Clair River and in Lake St. Clair, and in the Detroit River. Completion is called for by 1962.

The job is divided as follows: 16 million yards of hydraulic dredging; 24 million yards to be removed by dipper dredges and 4 million yards of ledge rock.

Though not primarily a part of the Seaway Project, basically the Great Lakes channel deepening is vitally connected with seaway navigation. In general, upbound channels will be deepened about six feet, while down-bound and two-way channels will be deepened from two to four feet.

The Economics of Pumped Storage. To complete this article by Dr. Charles Jaeger, published in our February and March issues, the following amendments and additions should be made to the bibliography:—

[18] A. Ammann. "Zur Pumpspeicherung in grossen Verbundnetzen, Beispiel der Vorarlberger Illwerke," 5th World Power Conference, Vienna, 1956, Paper 115H/23.

[19] K. Widdmann. "Probleme im Elektromaschinen und-anlagenbau bei Pumpspeicherwerken," 5th World Power Conference, Vienna, 1956, Paper 107H/19.

[22] V. Bodson. "L'aménagement hydro-électrique de la vallée de l'Our," 5th World Power Conference, Vienna, 1956, Paper 44H/8.

[25] H. Gerber. "Künstliche Speicherung," *Schweizerische Bauzeitung*, Vol. 74, Nos. 9 and 10, March 3 and 10, 1956.

[27] R. Thomann. "Die Speicherpumpenanlage des Etzelwerkes," *Wasser-und Energiewirtschaft*, No. 6/7, 1950.

[29] R. L. Hearn. "The Sir Adam Beck-Niagara G.S. No. 2," WATER POWER, July 1956, pp. 246-254.

[30] J. Frank. "Two New Pumped-storage Plants in Germany: Geesthart and Happurg." *Siemens Zeitschrift*, Vol. 30, No. 5, pp. 269-273, June 1956.

Glen Shira Pumped-Storage Scheme. In connection with our description of this scheme in our January and February issues, our attention has been drawn to the fact that The Harland Engineering Co. Ltd., not only manufactured but also designed the pump for the Sron Mor power station. An earlier article on this scheme was published in our April, 1952, issue, which dealt with model tests which The Harland Engineering Co. Ltd. carried out at their works on a one-fifth scale model of the pump.

The Durance Project

Following the outline of the great project in South-Eastern France in the Editorial of our issue of January, 1957, we start below the first of a series of more detailed articles contributed by Peter O. Wolf, B.Sc.(Eng.), A.M.I.C.E., A.M.I.W.E.

PART ONE

ON January 5, 1955, the French Parliament passed a law declaring the harnessing and utilisation of the River Durance to be a matter of national importance and of immediate urgency. This culmination of more than half-a-century's preparatory work enabled a start to be made on some engineering works of the first magnitude.

The scope of the new development is very wide. The Durance at present provides irrigation water for one of the most fertile parts of the Provence, itself one of the richest areas of France, and industrial and domestic water supplies for Marseilles and other towns; it has a vast power potential which is to be harnessed for the further industrial development of the country; and it is subject to severe floods and droughts which threaten, in turn, to inundate and starve the valuable agricultural areas and require large flood-control and storage works.

The attitude to the Durance development adopted by the French national and local authorities as well as by the national electricity board, Electricité de France, is proof of the spread of broad, humane principles throughout the field of postwar reconstruction. Although the electrical output from the whole valley will be very large (perhaps 11,000 million kWh per annum) and its unit cost, at approximately 3 francs (3 farthings) per kWh, remarkably low, the advantages to which Mons. Giguet, of Electricité de France, drew particular attention during his recent meeting* concerning the general economic and social rehabilitation of the area. The provision of storage works will greatly increase the guaranteed water supply for domestic use, so making it possible to increase both the standard of living of the individual and the total number of inhabitants in the area. The same increase in the minimum water supplies, the rise in the prosperity of the agricultural community, and (though this will be less important) a cheap and abundant supply of electric power, will attract industry and, it is hoped, convert a largely agricultural into a mixed community with a healthier economy. Agriculture will also greatly benefit from the virtual elimination of destructive floods and the avoidance of serious droughts during the irrigation season; also, though to a lesser extent, from an improvement in the water-distribution and control arrangements on the irrigation canals. Another valuable potential field of development, in an area which is close to the Mediterranean and reaches up to the main ridge of the French Alps, will be the tourist trade, which should be powerfully stimulated by the growth of agriculture and industry and the improvement in communications.

* R. Giguet, "A French dual-purpose scheme: the Durance project and the Serre Ponçon dam," joint meeting, Inst. Civil Engrs. and Ing. Civils de France, December 6, 1956, Proc. I.C.E., April 1957.

Topography and Geomorphology

After the Saône, the Durance is the most important river flowing into the Rhône which it joins as its last left-bank tributary. The catchment (see Fig. 1) of the Durance includes more than one-quarter of the French Alps; it rises to 4,103 metres (13,450 ft.) in the Pelvoux Alps, and at its mouth near Avignon (elevation 12 m.) its area amounts to 14,225 sq. km. (say 5,500 sq. miles). Many valleys join that of the Durance, the most important being those of the Guil, the Ubaye, the Bléone, the Asse and the Verdon on the left bank, and the Guisane and the Buech on the right. The Coulon, with a catchment area of nearly 1,000 sq. km., joins the Durance about 20 km. from Avignon, but because of its small average flow of 5 cu. m. per sec., and its low elevation, does not make any appreciable contribution to the discharge or the power potential of the basin.

It has been found convenient to divide the Durance valley into three reaches which differ from each other in slope and other characteristics, such as hydrology, to be discussed later. The Upper Durance, about 75 km. long, extends down to the site of the great Serre Ponçon dam, just below the mouth of the River Ubaye, and with an average slope of 1 in 70 falls to an elevation of approximately 670 m.; at Serre Ponçon the catchment area amounts to 3,600 sq. km. (1,390 sq. miles) and has a mean altitude of just over 2,000 m. (6,600 ft.). The middle reach, with a length of about 125 km., falls to an elevation of approximately 256 m., at the intake at Cadarache, just downstream of the mouth of the River Verdon; the catchment area at Cadarache amounts to 11,700 sq. km. (4,500 sq. miles), and its mean altitude is still 1,290 m. (4,250 ft.). From the mouth of the River Verdon, for nearly 100 km. to the Rhône, the Lower Durance flows through the agriculturally most valuable area without, as we have seen, receiving any further tributaries of note.

It is generally accepted that the Lower Durance is, in geological terms, a recent watercourse, formed by the "capture" of the Durance by the Rhône during the middle of the Quaternary Age. Before then, the Durance flowed southward, from where Mallemort stands now, through the Pass of Lamanon and through the Plain of Crau to the Mediterranean. To reach the mouth of the Rhône from Mallemort, at present, the water of the Durance covers a distance

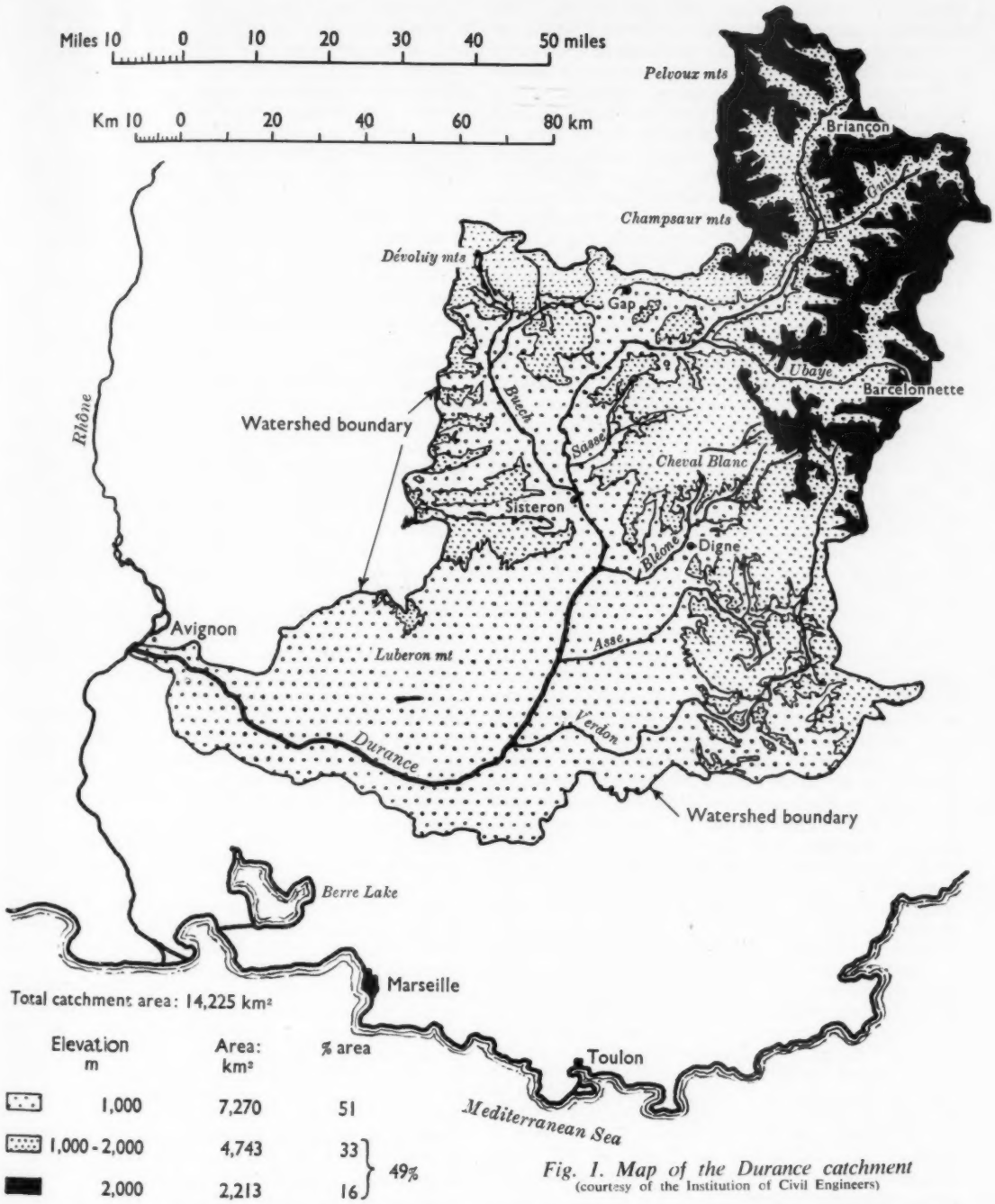


Fig. 1. Map of the Durance catchment
(courtesy of the Institution of Civil Engineers)

of over 100 km. The proposed power canal will divert some of this water southwards, from Mallemort, over a distance of only 30 km. to Lake Berre which is at the same level as the Mediterranean, so making conditions somewhat similar to those of the early Quaternary Age, in order to steepen the slope.

Hydrology

Rainfall and river-flow measurements in the Durance basin have been carried out systematically for over 50 years, and the mean values now computed may be taken to be close to long-period averages.

Average annual precipitation on the Durance catchment ranges from over 2,500 mm. (100 in.) to less than 600 mm. (24 in.). The Upper Durance receives the run-off from the bulk of the area subject to an annual fall exceeding 2,000 mm. (80 in.). The greater part of the area with a fall between 1,000 and 2,000 mm. per annum drains to the Middle Durance. Virtually the whole of the area adjacent to the Lower

Durance receives less than 1,000 mm. (40 in.), with large tracts subject to less than 600 mm. (24 in.) per annum. The irrigated belt to the south of the Lower Durance has indeed been called a semi-arid zone.

The precipitation in the highest region is largely in the form of snow, and there are substantial glaciers in the Pelvoux range of mountains to the West of Briançon. These glaciers, in common with the other Alpine ones, are at present receding. In view of their importance as a source of summer run-off, the present recession, with the possibility of the disappearance of glaciers in the foreseeable future, suggests that without other forms of storage there would be a danger of increasingly severe summer droughts seriously affecting both irrigation and power supplies.

At the lower end of the Upper Durance, at Serre Ponçon, which lies 2 km. downstream of the mouth of the River Ubaye, the catchment area of 3,600 sq. km. yields a mean annual volume of water of 2,670 million cu. m. (say 85 cu. m. per sec. or 3,000 cusecs). The maximum design flow through the turbines in the Serre Ponçon power station, of 300 cu. m. per sec., will be discussed later. The lowest discharge recorded at the downstream end of the Upper Durance amounted to 16 cu. m. per sec. (560 cusecs). Floods in that area have not exceeded 800 cu. m. per sec. during this century, but there is a record of a much heavier flood, in 1856, the peak discharge of which has been estimated at approximately 2,000 cu. m. per sec. (or 70,000 cusecs). Analytical work on the design flood reaching Serre Ponçon will be described later.

The gauging site at the downstream end of the Middle Durance is at Cadarache, near the site of the intake to the Lower Durance power canal, just downstream of the mouth of the River Verdon. The catchment area of 11,700 sq. km. feeding this station yields 6,150 million cu. m. per annum, an average dischage of over 195 cu. m. per sec. (6,900 cusecs). In August the discharge has been known to fall to as low as 45 cu. m. per sec. (1,600 cusecs). At the other end of the range, a flood of nearly 3,000 cu. m. per sec. (over 100,000 cusecs) was experienced in 1951, and the peak of the worst flood of which we possess a water-level record (1886) may have exceeded 6,000 cu. m. per sec. (210,000 cusecs).

Severe floods most frequently occur in October and November when the meteorological conditions favouring heavy rainfalls are most frequently present in the local weather system and when, in addition, there is some run-off from the melting of autumn snow.

Table I shows the approximate distribution in time of the run-off measured at the junctions of the three reaches. The smallness of the difference of flows in the summer is consistent with the picture of glacier-fed summer flows; the large difference in the winter is evidence of snow falling and lying on the higher mountains while the corresponding rains on the lower areas cause rapid run-off.

TABLE I—APPROXIMATE RUN-OFF DISTRIBUTION IN TIME

River Durance at	Catchment area sq. km.	Run-off in million cu. m. and as a percentage of the annual total				
		Jan.-Mar.	Apr.-Jun.	Jul.-Sep.	Oct.-Dec.	Whole year
Serre Ponçon ...	3,600	270 10%	1,310 49%	660 25%	430 16%	2,670 100%
Cadarache	11,700	1,450 23%	2,250 37%	900 15%	1,550 25%	6,150 100%

The sediment load carried in the Durance and its tributaries is heavy, as would be expected in rivers of such steep gradients and with a recent history of "capture" and consequent disturbance. Where appropriate, certain reservoirs will, therefore, include considerable storage volumes to accommodate deposits. Other sediment problems studied include the behaviour of the river bed following the rather violent changes in régime; the means of keeping sediment out of the Lower Durance canal; and the problem of keeping the water discharging into Lake Berre free of silt so as not to cause any deposits in the harbour installations in the lake.

Ground-water aspects of the Durance project have been studied so fully that a whole section in a later issue will be devoted to their description.

Irrigation

There is some irrigation use of Durance water in the middle reach of the valley where 8 canals abstract a total of approximately 10 cu. m. per sec. (350 cusecs).

The bulk of the area which it at present artificially irrigated amounts to approximately 75,000 hectares (185,000 acres) and is situated in the Departments of Vaucluse to the north and Bouches du Rhône to the south of the Lower Durance. Soil surveys have shown that, with irrigation, a further 25,000 hectares (approximately 100 sq. miles) could be turned into fertile agricultural land.

The present network of 15 major irrigation canals has grown over some eight centuries. Among them are:—the St. Julien canal, to Caumont, originally built by the Bishops of Cavaillon before 1170; Craponne's canal, to the neighbourhood of Arles outside the Durance basin, which is an extension of the canal constructed by Adam de Craponne in 1554, to convey approximately 70 cusecs to the Salon area; with a capacity of 25 cu. m. per sec. (nearly 900 cusecs) this canal is the largest in the basin; the Carpentras canal, carrying up to 12 cu. m. per sec. (425 cusecs) northwards out of the Durance catchment area and irrigating the greater part of the Vaucluse: this is one of the most modern and best equipped canals.

An additional canal of special interest diverts 14 cu. m. per sec. (nearly 500 cusecs) of Durance water, which constitutes the sole supply of fresh water to Marseilles.

In the growing season of 1952 the flow abstracted by all these canals from the Lower Durance was gauged at 114 cu. m. per sec. (4,000 cusecs). With the minimum discharge in the river falling to less than half of the flow needed by agriculture, a law had had to be passed in 1907 setting up a committee with powers to regulate the amounts which could be diverted to the upper canal intakes. Since the Castillon reservoir began to regulate the flow of the River Verdon in 1948, catastrophic drought conditions have been avoided, but only a large amount of additional storage (most of it to be provided at Serre Ponçon) will make it possible to raise the minimum flow in the Durance to the figure required to satisfy agricultural demands present and future.

The present network has grown independently so that each canal has its own intake weir and con-

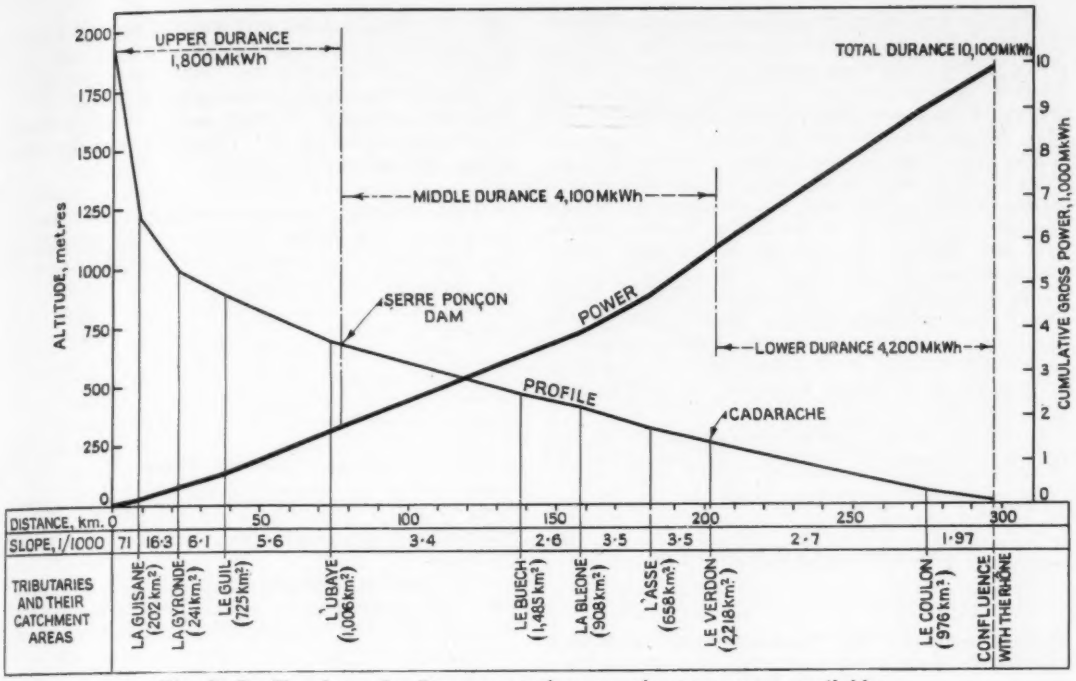


Fig. 2. Profile along the Durance, and curve of gross power available
(courtesy of the Institution of Civil Engineers)

trol works on the Durance, in some cases several dozen miles from the area to be irrigated. The projected power canal for the Lower Durance development will make it possible to abandon these separate intake works and to supply each irrigation canal, at the point closest to its area of irrigation, with water from the power canal which normally runs at a higher level than the river. This will also benefit power production because the water will have passed through some of the power stations before being diverted for irrigation.

The value of irrigation measured in terms of the improvement of agricultural production on the 75,000 hectares now irrigated may be taken to be a large proportion of the estimated total annual value for that area of £30 million. If a purely economic comparison is desired, and disregarding all other considerations, this improvement has to be set against the increase of approximately 600 million kWh in the annual power output which would be possible if all diversion of water for irrigation ceased.

Energy Potential and Development Plans

Compared with the development of water-power schemes in other areas of the Alps, the Durance basin has received little attention in the past quarter of a century, and this in spite of favourable conditions of large flows and steep gradients. In parenthesis it may be stressed that the comparative neglect in the past has the great advantage that modern design knowledge and modern plant, both constructional and operational, will lead to a degree of efficiency in the works to be constructed which could not have been even approached before the last war.

The first power stations in the basin, Ventavon on the Middle Durance and L'Argentière on the Upper Durance, both dated 1909, were masterpieces of their time. In the following 15 years Les Claux, Le Fournel, and Champcella were added on the Upper Durance; and Le Poët below Ventavon, and La Brillanne, Le Largue, and Sainte-Tulle in series, on the Middle Durance. Since 1935 there have been only two major new works, Castillon and Chaudanne, both on the River Verdon.

Fig. 2 shows the gross annual energy available on the River Durance itself to be over 10,000 million kWh. The additional energy potential of the tributaries is approximately half that figure. Present preliminary estimates indicate that 10,000 out of the total annual potential of 15,000 million kWh of the whole basin may be obtained at a low unit cost.

Detailed plans for a development of a total of 6,200 million kWh per annum are now under consideration, as summarised in Table II.

TABLE II.—SCHEMES IN OPERATION AND UNDER CONSTRUCTION

	Annual energy output		Installed capacity MW
	%	million kWh	
1. Schemes in operation in 1957			
(a) Upper Durance	23	1,100	275
(b) Middle Durance ..	64		
(c) Verdon	13		
2. Schemes under construction		1,100	380
3. Third stage		2,900	850
4. Fourth stage		1,100	280
Total		6,200	1,785

The schemes under construction are Serre Ponçon (320 MW, 700 million kWh per annum plus increases in the output of existing stations downstream due to the flow regulation in the Serre Ponçon reservoir), and the first of the Lower Durance Projects, at Jouques (62 MW, 325 million kWh per annum).

The third stage of construction is intended to include Curbans, Sisteron, Oraison, Manosque, a second station at Sainte-Tulle, and Beaumont, on the Middle Durance, Sainte-Croix on the Lower Verdon, and the next two stations downstream of Jouques, Sainte-Estève-Janson and Mallemort, on the Lower Durance.

The fourth stage would comprise Vallouise on the Upper Durance, Salignac on the Middle Durance, and Salon and Saint-Chamas on the diversion canal to Lake Berre, as well as the enlargement of some existing power station, namely Ventavon, Le Poët, La Brillanne, and Sainte-Tulle.

In order to produce the required annual energy output with a reasonable installed capacity and at the times required, a large amount of reservoir storage will have to be provided. (As we have seen, this substantially coincides with the requirements of irrigation and flood control.) Table III shows the "live," or utilisable, storage in the main reservoirs, all of which are situated upstream of Cadarache where the mean annual flow amounts to 6,150 cu. m.

TABLE III.—LIVE STORAGE IN THE MAIN RESERVOIRS

River	Reservoir	Live storage capacity million cu. m.
Durance	Serre Ponçon	900
Verdon	Castillon	120
	Sainte-Croix	500
Buech	Serres	220
	Total	1,740

(To be continued)

Book Reviews

Energie potential des Niederschlages im Oesterreichischen Bundesgebiet. (Energy Potential of Precipitations on the Austrian Federal Territory.) 2nd Supplement to the Austrian Hydro-Power Cadastre published by the Federal Ministry for Trade and Reconstruction, 1, Stubenring, Vienna, 1. 1956. Price 500 Austrian shillings.

This general study on the energy potential of the Austrian Territory is directly inspired by two previous publications of the United Nations Economic Commission for Europe: the first publication (W/EP.113) is dated May 6, 1950, the second, more important, E/E.C.E./EP/131, is dated May 18, 1953, and entitled "Hydro-Electric Potential in Europe and its Gross, Technical and Economic Limits." The aim of this second paper was to elaborate a method for estimating the hydro-power potential of a country, starting from the measured rainfall from which the gross hydro-power potential is determined. This figure is then compared to the "technical potential" or power potential which could technically be developed, as based on more detailed technical studies. The "economical potential" only retains those technical projects which are economically sound. Both the technical and the economical potential depend on the skill of the engineers in charge of the investigation, on the progressive evolution of the technique and on economic circumstances. The main result of this study by the United Nations Economic Commission for Europe is that the output considered economically possible represents about 17·8% to 19·7% of the gross yearly potential at full utilisation. It is expected that this figure, obtained by direct and detailed studies made in Switzerland, Austria, Germany, etc., is more or less a constant and can be extrapolated to other countries where the only available data (rainfall records and topography) concern the gross yearly potential.

The Austrian publication concerns only the estimate of the gross yearly potential in the sense defined by the U.N.E.C.E., and the Austrian Federal Ministry for Trade and Reconstruction estimate that the results of their careful investigations are of direct interest to many other countries involved in similar research.

TABLE I

Level above sea	Density			Depth of snow
	East or north slope	West or south slope	Average	
m				cm
931	—	—	0·43	40
1,185	0·36	0·43	0·41	70
1,485	0·41	0·44	0·42	?
Average	0·36	0·42	0·42	56

The method of computation adopted by the Austrian Ministry differs on several points from the method used by the Economic Commission for Europe. The E.C.E. base their calculations for gross power output on the estimated run-off, whereas the Austrian Ministry base all their calculations on the actual rainfall. To justify their point, the Austrian Ministry experts compare some run-off figures as estimated on the basis of the recommendation of the E.C.E. and as actually computed from their own data. The difference in the run-off versus rainfall coefficient varies as much as 0·599 (estimated) to 0·850

TABLE II

Level above sea level	Winter			Summer		Yearly total
	Rainfall	Water contained in snow	Water available for run-off	Rainfall	Water available	
m.	mm.	mm.	mm.	mm.	mm.	mm.
500	450	7	443	850	857	1,300
1,000	620	116	504	1,080	1,196	1,700
1,500	750	500	250	1,280	1,780	2,030
2,000	820	820	—	1,460	2,280	2,280
2,500	870	870	—	1,640	2,510	2,510
3,000	920	920	—	1,790	2,710	2,710

(actual value) for the Möll district in Austria. The difference is less for other districts but remains quite appreciable.

The Austrian Ministry experts have decided to divide the yearly rainfall into a winter period (October-March) and a summer period (April-September) and to estimate as accurately as possible the power retention caused by snow and ice during the winter period. The usual procedure of meteorologists consists in melting the snow each month and adding the volume of melted water so obtained to the rainwater to get the monthly rainfall. For power estimates, this procedure yields erroneous results, as the snows actually melt at the end of the winter when the water finally becomes available for power production.

The Austrian experts went to great trouble in determining not only the exact depth of snow, but the true density of the snow at different altitudes above sea level and for different orientation of the slopes. The data in Table I may be of general interest (see page 16 of the General Report). On higher levels (2,294 to 2,910 m.) the snow density varies between 0·41 and 0·58 and the depth of snow between 88 cm. and 434 cm.

Table II (see page 19 of the General Report) gives a good idea of the type of research carried out by the meteorologists of the Austrian Ministry. Such a table is of the highest interest for correct interpretation of the climatic conditions in the Alps and for the correct estimate of the available water power. This division between winter and summer is maintained during the following stages of calculation up to the final stages of power estimate.

The third point on which the method of computation proposed by the Austrian Ministry differs from the methods used by the E.C.E. concerns the method of integrating the partial products of discharge × head to get the total power output of an area. For this integration the E.C.E. experts propose to divide the area on which the integration is to be carried out in a rectangular mesh of small elemental areas and to integrate by addition of all these elemental products of discharge × head. The Austrian experts trace two superimposed maps of the area. The first is the conventional map with contour lines . . . $h^* - \Delta h^*$, h^*, $h^* + \Delta h^*$ . . . and the other indicates lines of equal rainfall N. The power calculation begins with an integration of the discharge dQ at level h^* (say between the contour lines $h^* - \Delta h^*$ and h^*). If N is the rainfall, then the integral is $dQ(h^*) = \int \frac{N d^2f}{df}$ where d^2f are small elemental areas for which N can be considered as constant. The d^2f are taken as small rectangles $d^2f = dn\ dt$ and dn is perpendicular to the actual contour lines. df is the area between the two contour lines $h^* - \Delta h^*$ and h^*. The total output E over the whole area is obtained by writing:

$$Q(h) = \int_{h}^{h\ max} dQ(h^*) \text{ and } E = K \int_{h\ min}^{h\ max} Q(h)\ dh$$

$K = 0{\cdot}002725$ when metres and kWh are used. Comparative estimates made by the Austrian experts with their own method and with the method suggested by the E.C.E. show differences varying between 9% and 19%. It is fair to say that the E.C.E. worked on a small-scale map of all Europe with large square meshes whereas the Austrian experts worked with great accuracy on a large-scale map of Austria alone (scale 1 : 500,000).

The Austrian publication consists of a general report, which makes most interesting reading, and a series of maps and diagrams, most of which are beautifully printed.

This publication of the Austrian Ministry for Trade and Reconstruction is an extremely valuable contribution to the methods of estimating the hydro-power potential of any country and will be of great help to all people concerned in similar computations

CHARLES JAEGER.

ASTA Publication No. 1, Revision 1956. The Association of Short-Circuit Testing Authorities (Inc.) 36 Kingsway, London, W.C.2.

This new edition gives an up-to-date account of the Association, its method of operating, and a brief description of some of the plant at its testing stations. The new brochure gives a full account of the facilities available to British manufacturers at these stations, and shows how their equipment is tested in complete confidence both for experimental purposes or to obtain a Certificate of Rating. The brochure is intended to describe the operation of the Association as it relates to its important function of proving electrical equipment, and as a certifying authortiy where the equipment complies with a British Standard or published ASTA Rules. It does not, however, touch on the important part played by the Association in collating the experience on testing obtained through its short-circuit testing plants which ultimately form the basis of ASTA Rules and to some extent provide a guide to those concerned with the drafting of relative British Standards.

Statistical Yearbook of the World Power Conference (No. 8, Data on Resources and Annual Statistics for 1952-1954). Edited by Frederick Brown. Percy Lund, Humphries & Co. Ltd., 12 Bedford Square, London, W.C.1. Price £3 3s. 0d. net.

This biennial publication represents one of the many important services rendered to the world by the World Power Conference, as it gives a statistical digest of world power resources and the state of their development so far as it has been possible to procure the information. The material covers solid, liquid and gaseous fuels, water-power resources, and electrical power, and is arranged in a standardised form that has become familiar from previous editions. Reference to the tables on water-power resources and development in the various countries reveals at once one of the fundamental difficulties in compiling world statistics, for there are a number of countries possessing substantial water-power resources which do not appear in the tables, evidently because they have not furnished the necessary data. In this respect the present edition is a marked improvement on the previous one, although one or two important countries have dropped out. Even so, the coverage is comprehensive, but we are sure that the editor looks forward as sincerely as we do to the time when he is in a position to make the coverage complete.

Mobile Cranes. Publication No. 507 received from Ransomes & Rapier Limited gives a specification of the 6 and 7 Fast Standard mobile cranes manufactured by this firm. These are designed for loads up to 6 and 7½ tons (17,050 and 21,350 lb. American rating) and have travelling speeds of up to 20 miles per hour.

The Stornorrfors Turbines

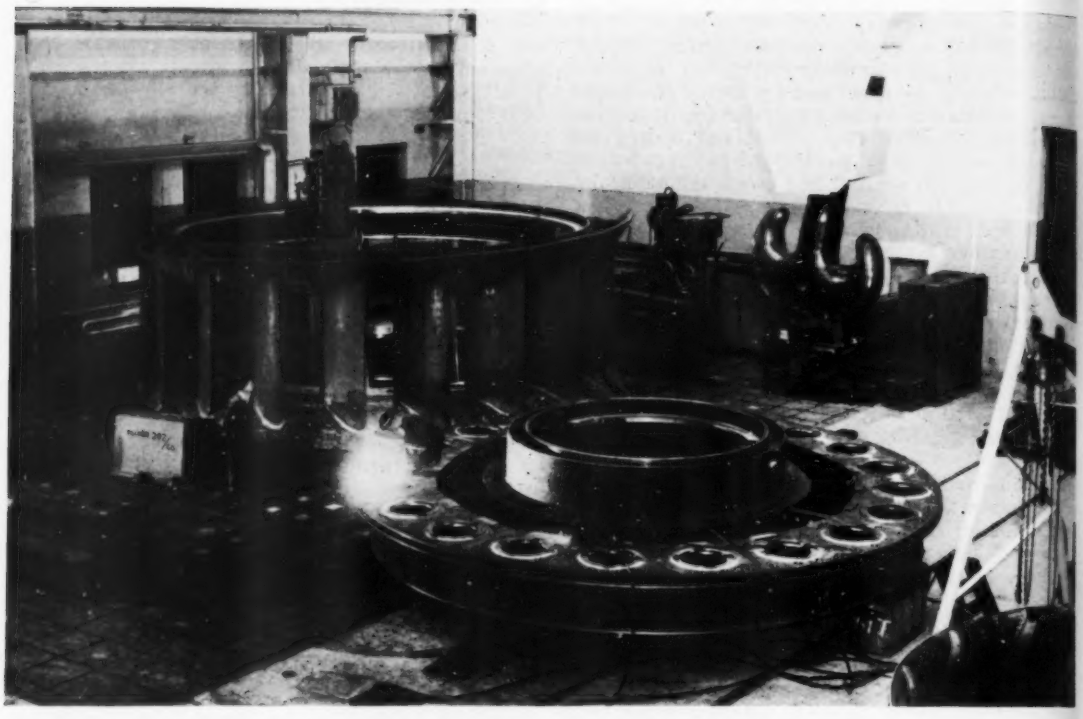


Fig. 1. Stayring and head cover in course of assembly

BY making use of the accumulated head from a number of rapids in the lower reaches of the Ume River in northern Sweden, it has been possible for the Swedish State Power Board to obtain a total head of approximately 75 m. which will be utilised to produce power in the Stornorrfors power plant now under construction. This plant will replace some older stations that previously utilised part of the rapids, and its tailwater will be at sea level.

The ultimate discharge through the station will be 800 cu. m. per sec. In the first stage, however, only three units will be installed, each designed for a discharge of 200 cu. m. per sec., corresponding to a guaranteed output of 178,120 h.p. at a net head of 73 m. and a speed of 125 r.p.m. An output of 200,000 h.p. is guaranteed at 75 m. net head, thus making these turbines the largest in the world with regard to output.

In accordance with recent practice in Sweden, this plant will be of the underground type, excavated in the solid rock. The water will be led to the turbines through vertical penstocks, one for each unit, lined with steel plate and with concrete grouted in between the steel plate and the surrounding rock. At the head of the penstocks tainter gates are installed, with operating mechanism designed for quick closure and provided with other special devices made necessary by the absence of shut-off valves at the spiral inlets. The water from the turbines is discharged through a 4 km. long tailrace tunnel, common to the whole station, having a cross-sectional area of 390 sq. m., and

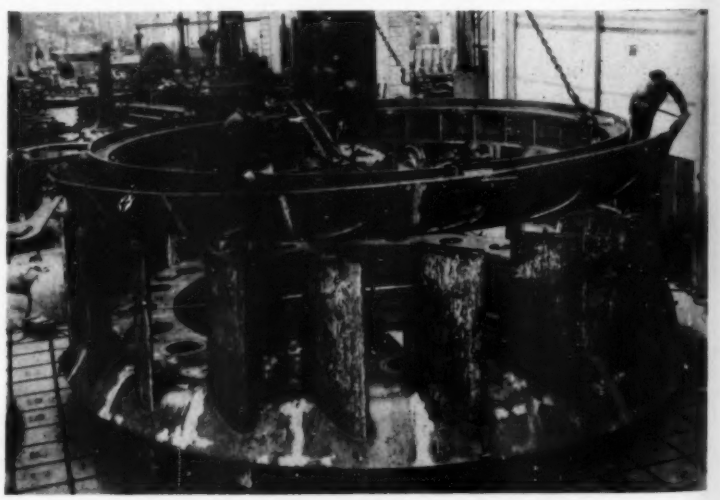


Fig. 2. Assembling a stayring

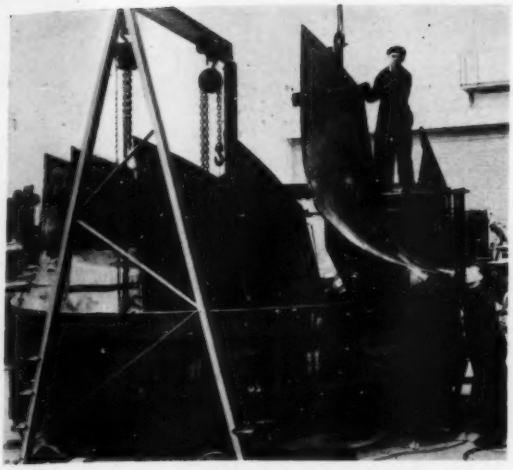


Fig. 3. Placing a blade in position

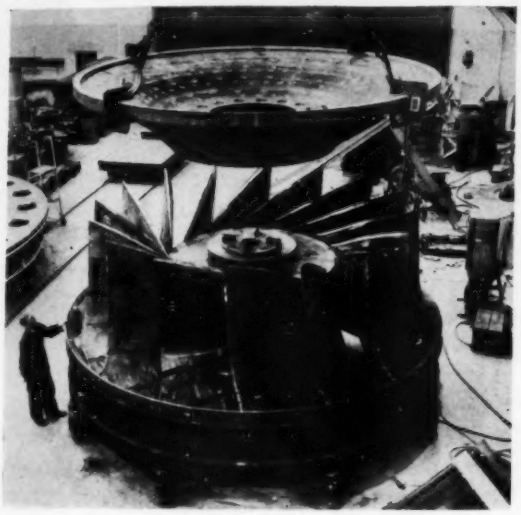


Fig. 4. Lowering top of runner

Fig. 5. Runner ready for welding

thus believed to hold the world record for this type of tunnel.

The large output per unit naturally calls for turbines with very large dimensions, as the design head is only 75 m. It has been only due to the fact that the plant is situated on the coast, making possible sea transport, that it has been possible to avoid splitting the runners, even if this had been possible at all at the head in question. In any case the splitting of the runners would have been a very complicated and costly solution. The turbines have been ordered from Nydqvist & Holm Aktiebolag (NOHAB) and are being manufactured in their Trollhättan works situated on the Göta River, making possible direct shipment by boat from their works. The question of transport naturally also arose when a subcontractor for the runner castings was to be chosen, and therefore only foundries having access to quaysides could be considered.

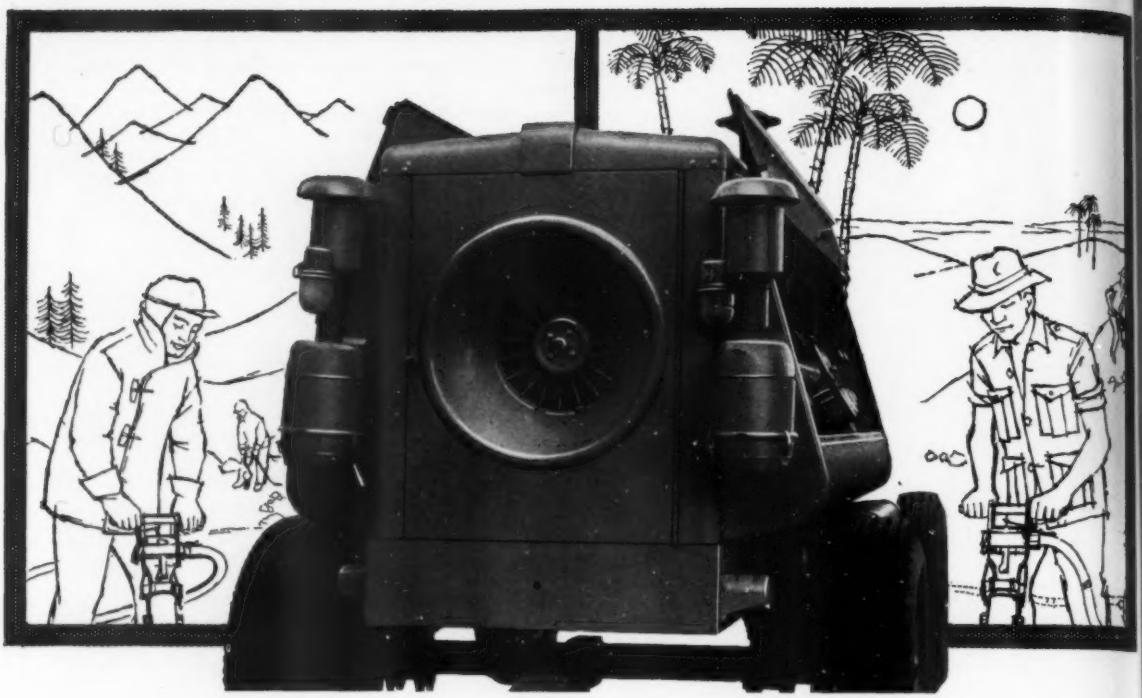
The runners will be made entirely of stainless steel. Although it would have been possible to cast them in one piece, in spite of the fact that their finished machined weight is 67 tons, NOHAB decided to cast the hub and blades separately and weld them together. The main reason for this procedure is that greater accuracy is attained on the blade angles and openings, and it is also possible to grind and polish the blades to a very fine surface finish and to machine the water-passage surfaces of the hub and band. In connection with this it can be mentioned that a very high maximum efficiency has been guaranteed.

As the Swedish State Power Board would accept only martensitic cast steel, a great many problems in connection with the welding had to be solved. NOHAB have therefore co-operated with foundry and welding specialists in developing and adopting a welding procedure involving various stages of welding and heat-treating processes that will guarantee a perfectly sound and reliable runner. The problems have been solved and the runners are now being manufactured according to the method developed. We understand that it has already been possible for another Swedish turbine manufacturer to make use of this method, developed at Nydqvist & Holm Aktiebolag when manufacturing smaller runners than those for Stornorrfors.

Other large turbine parts, such as stayrings made according to NOHAB's patented design, head covers, etc., are fabricated from steel plate and welded instead of making them from cast steel or cast iron. This ensures homogeneous material and makes a lighter design possible. NOHAB have specialised on welding of this type for many years, and have recently installed the largest annealing furnace in northern Europe, making it possible to stress relieve even the largest turbine parts. The spiral-casing welds are X-ray examined.

In other respects the turbines will be of conventional design. The main guide bearings will be of NOHAB's self-lubricating type, as described in our December 1954 issue.

In accordance with normal practice on large units, the governing system will be divided up into three separate groups, i.e., servomotors with distributing valves, oil-pressure units, and actuators. The servomotors will be placed directly on the turbine head covers, thus confining the operating forces within the turbine structure itself and eliminating the disadvantages encountered when having the servomotors placed in the concrete structure. The actuators will be of the



Air-cooling proves best in any climate

Whatever the climate, in any working conditions, portable compressors with air-cooling for both engine and compressor have proved superior in every way to water-cooled portables. There are no cooling agents to overheat or freeze up. The air-cooled units allow a higher working temperature, which means far less wear on cylinders, pistons and rings, especially if high sulphur content diesel oils are used. And they reach working temperature in half the time taken by water-cooled units—so starting wear is cut down considerably. As most of the troubles in water-cooled units arise from defects in the cooling system, *the mechanical reliability* of air-cooled units is much greater. Moreover their lower weight makes transportation and handling easier.

THE MOST COMPLETE RANGE OF AIR-COOLED COMPRESSORS IN THE WORLD

Atlas Copco compressors with full air-cooling, range from the 600 cu./ft. per minute type illustrated to one delivering 36 cu./ft. per minute—the largest and most comprehensive range in the world.

Every model in the range has a standard engine cylinder, and there are only a few types of compressor-cylinder. This ensures simplified spares stocking and easier service and maintenance.

It should be noted that most Atlas Copco air-cooled portables have engines manufactured by *Deutz*—the world's leading firm in the design, development and manufacture of air-cooled diesel engines.

The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further details of the equipment featured here, please contact your local Atlas Copco Company or agent, or write to Atlas Copco AB, Stockholm, 1, Sweden.

Atlas Copco

MANUFACTURERS OF STATIONARY AND PORTABLE COMPRESSORS, ROCK-DRILLING EQUIPMENT, LOADERS, PNEUMATIC TOOLS AND PAINT-SPRAYING EQUIPMENT

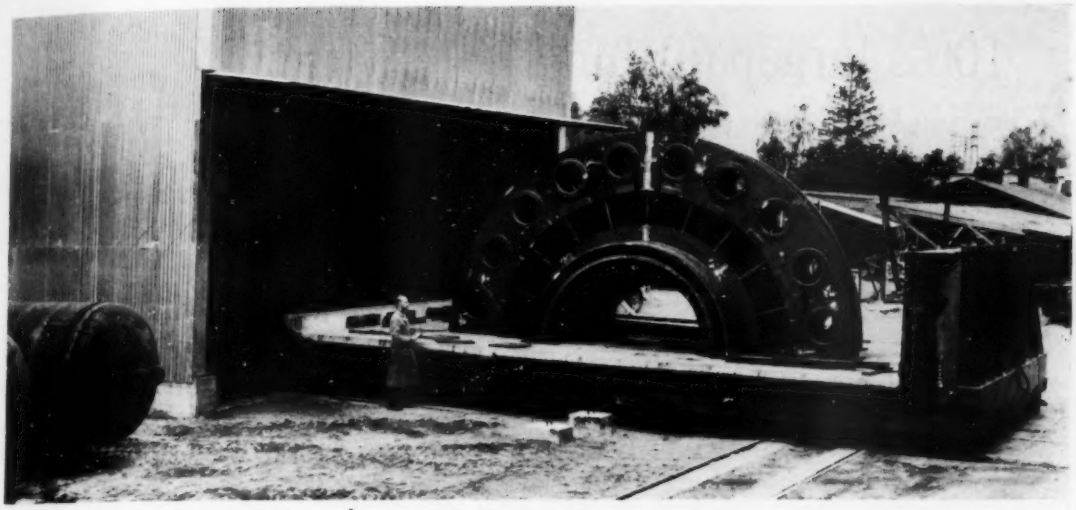


Fig. 6. Head cover about to enter the annealing furnace

NOHAB-ASEA electro-hydraulic type, as described in our October 1952 issue. Electro-hydraulic actuators are increasingly replacing the conventional mechanical-hydraulic type in Sweden, and NOHAB claim that the first electro-hydraulic actuators for large turbines were developed in collaboration between themselves and ASEA, although actuators of this design are now manufactured by other firms as well. The three different oil-pressure units will be interconnected to ensure uninterrupted operation of all the sets.

The plant will be equipped with modern instruments of various types as well as a great number of safety devices, so that the attending personnel can be reduced to a minimum.

The power station with three units installed is expected to be completed during 1959, but the first unit will be taken into service already during the autumn of 1958.

English Electric 65° Rise Motors

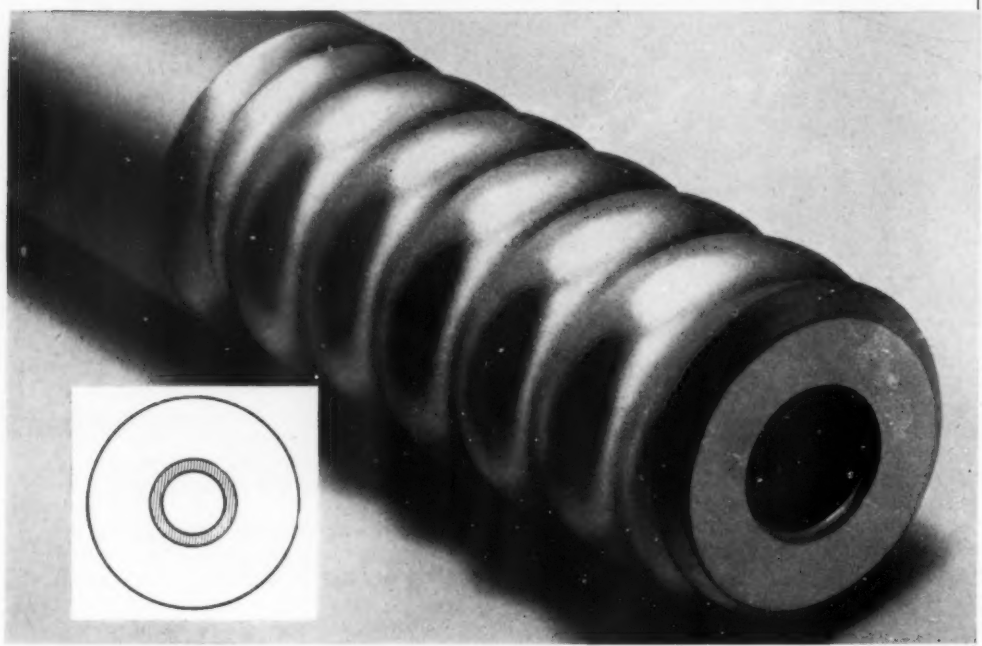
In the past most general-purpose British industrial motors have been rated for a temperature rise of 40°C. in the case of ventilated machines and 55°C. for totally enclosed machines. A new British Standards draft specification CW(ELE)6246 has been prepared for ventilated motors from ½ to 50 h.p. inclusive, in which advantage has been taken of class "E" materials and wire enamels based on polyvinylformal and polyurethane resins, which are becoming more widely used for insulating purposes. This specification permits a temperature rise of 65°C. above an ambient temperature of 40°C.

To take advantage of this new facility the English Electric Co. Ltd. has developed a complete range of ventilated British - Standard - dimensioned motors having outputs from ½ to 50 h.p., known as their Class "C" range. Due to the higher frame ratings possible with the newer insulating materials, these motors are smaller, lighter, cheaper and more efficient than the corresponding motors with conventional insulation. They are of the end-ventilated type, the air entering through the lower part of the endshield at the coupling end and emerging through a corresponding opening in the other endshield. There are no ventilating holes in the motor carcase itself, and the motor can be adapted for wall, ceiling or vertical mounting by withdrawing four bolts from each endshield and turning the endshield to a suitable 90° position.

It will be seen that the increased temperature rise permits a maximum temperature in the winding of 105°C., but the frame surface temperature will not normally exceed 90°C. in free air.

Although these machines have been designed in conformity with a draft British Standard, the Company has developed them largely with an eye to the overseas market, where it is hoped that they will prove an attractive alternative to high-temperature-rise motors manufactured in other countries.

100% larger flushing hole with Sandvik Coromant extension steels



½″ flushing hole in 1¼″ equipment

Better cleaning of the bore-hole . . . a higher rate of advance . . . less wear on the bit and less risk of steels sticking.

All these advantages are afforded by the large diameter flushing hole of Sandvik Coromant Extension Steels, because the 100% larger flushing hole, gives roughly 100% better flushing.

This increase in diameter *without any reduction in the strength of the steel* is achieved by the normally difficult technique of 'cold rolling', a process made practicable by Sandvik's long experience in the manufacture of high-quality Swedish steel. Cold rolling also gives a higher surface finish, which eliminates incipient cracks.

Special rope-thread makes fitting easy

A further advantage of Sandvik Coromant extension steels is the patented rope thread. This gives a solid and positive connection—and makes it extremely easy to join and unscrew the equipment. What's more, it has enabled Sandvik to contrive the *773* bottoming 4-point bit, which makes a bit adapter and coupling sleeve unnecessary. This bit is available in sizes from 1⅞″ to 3″.

The bits are fitted with Sandvik Coromant tungsten carbide inserts of the same quality that has made the Sandvik Coromant integral steels the most widely used drill steels in the world.

The world's leading drilling unit

Sandvik Coromant extension and drill steels and Atlas Copco drills have been developed to work together. Today, this drilling combination is widely used in major projects all over the world. It is responsible for the drilling of more than one thousand million feet annually.

Sandvik Coromant steels are supplied through Atlas Copco. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing compressed air equipment in ninety countries throughout the world. For further details of the equipment featured here, contact your local Atlas Copco Company or Agent, or write to Atlas Copco AB, Stockholm 1, Sweden.

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Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment

DSS 60

Contractors' Submersible Drainage Pump

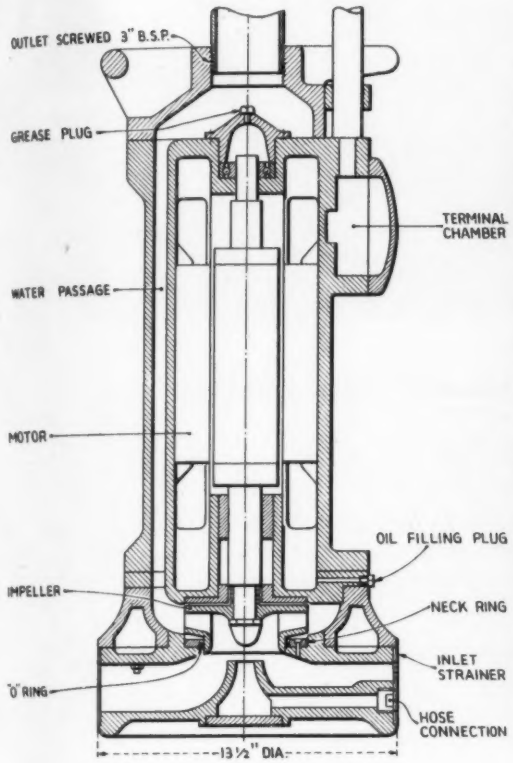


Fig. 1. Section through Sumo pump

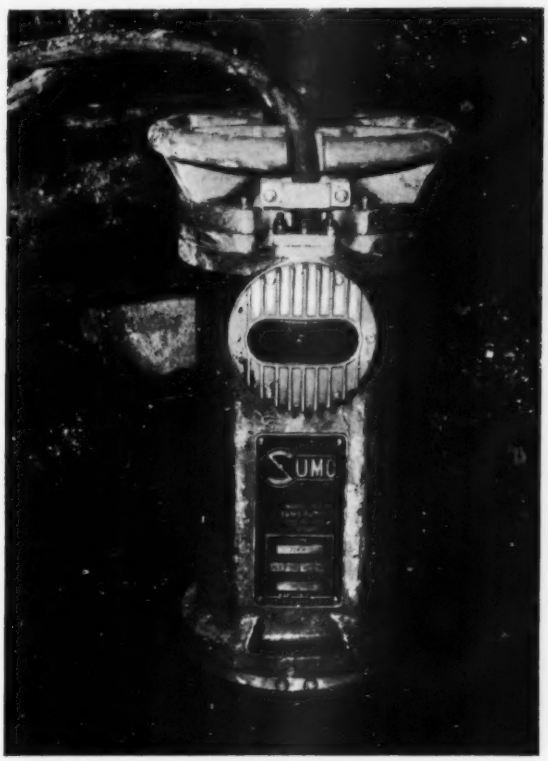


Fig. 2. Sumo pump on a building site

Sumo Pumps Limited, Crawley, Sussex, who have been making submersible borehole pumps for 20 years and have an American subsidiary at Stamford, Connecticut, have now placed on the market a fully submersible electrically driven pump for the use of building and civil-engineering contractors in dewatering excavations. It will handle dirty water containing grit up to $\frac{3}{8}$ in. in diameter, can run full bore or on snore indefinitely, will operate partly or completely submerged, and is designed to withstand the rough handling to which contractors' equipment is liable. It can be suspended by its rising-main pipe or by ropes, or it can stand on its own base, according to convenience.

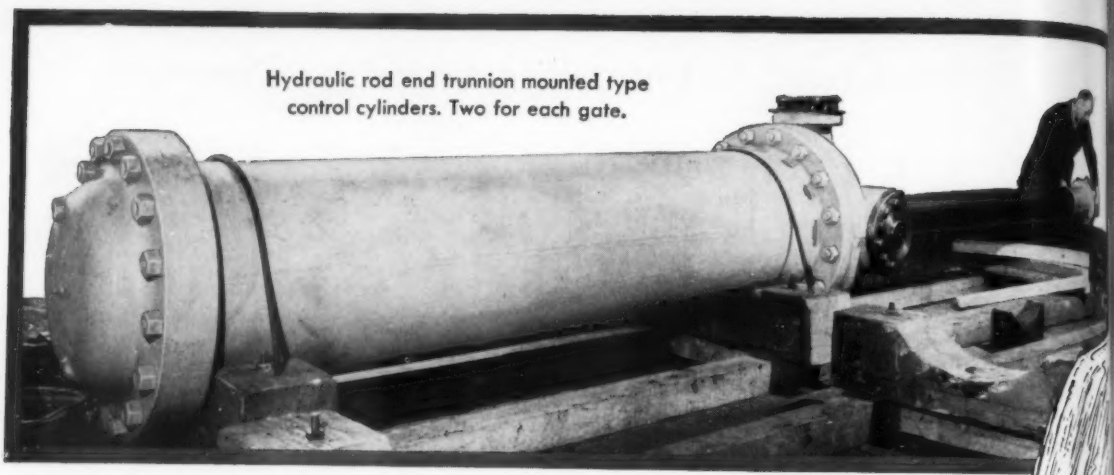
A view of one of these pumps at work on a drainage site appears in Fig. 2 and a sectional drawing is given in Fig. 1. The water entry takes the form of an annular opening immediately above the base, and is protected by a $\frac{3}{8}$ in. square-mesh stainless-steel strainer. The pump unit is mounted below the motor, where it can handle even a minimum depth of water, and consists of a single-stage bronze impeller working within a wearing ring and an O-section packing ring. A hose connection in the base of the unit enables the pump to be flushed out if necessary.

The interior of the squirrel-cage motor is filled with a light oil which lubricates the lower journal bearing; the upper bearing, which also takes the thrust load, is situated in a grease-filled compartment. The unit is supplied fully lubricated, ready for service and requires no priming on arrival. The stator windings are encased in wax and are sealed by the outer walls of the motor housing, the upper and lower flanges and a thin stainless-steel enclosure tube. On leaving the impeller the water flows through a coaxial passageway surrounding a large area of the motor-housing outer walls, thus cooling the stator. The pump can run on the snore for long periods without overheating, but an automatically resetting thermostat is embodied in the stator housing to give additional protection in case the water supply ceases completely and the pump is left running dry for too long, or if it jams accidentally.

The power cable, which is multi-core, heavily sheathed and metal braided, is led into a specially designed terminal box on the motor.

The pump casing is made of an aluminium alloy proof against sea-water corrosion. The foot has a wide rim and a handling ring is formed at the top so that the unit can be comfortably lifted, rolled like a milk churn, laid down and rolled like a drum, or pulled and skidded. The weight is 238 lb.

The unit can be supplied with either of two im-



Hydraulic rod end trunnion mounted type control cylinders. Two for each gate.

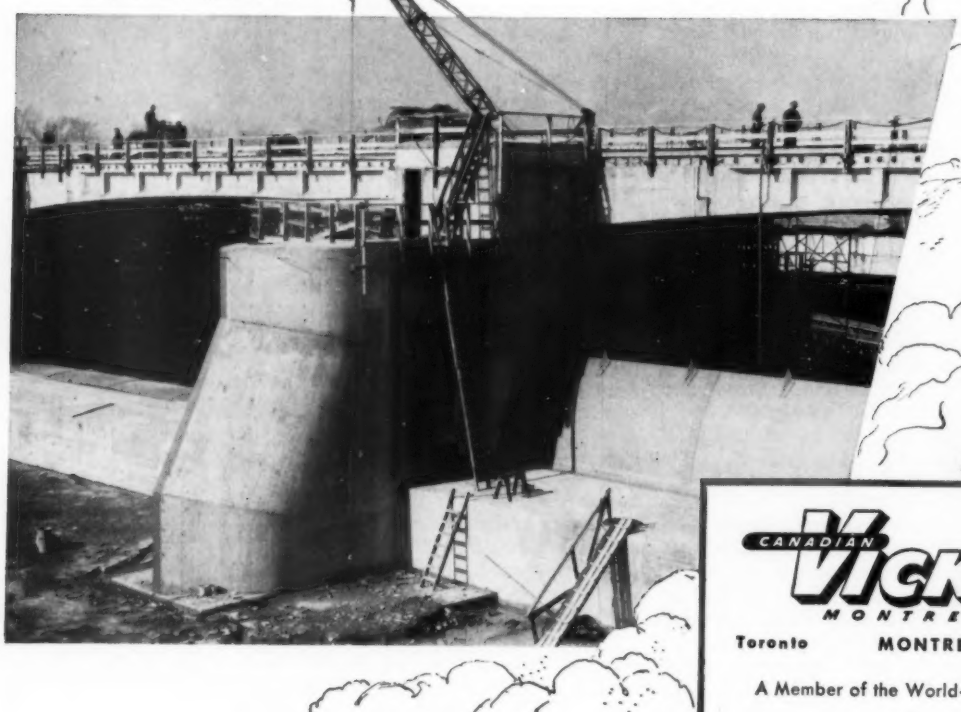
CONTROLLING THE FLOW OF NIAGARA

The flow of Niagara, one of Canada's greatest sources of electric power, is controlled by Vickers-built submersible gates of the "fishbelly" type.

Working with the M.A.N. Company, a Canadian Vickers associate, who designed the 100 ft. wide section welded gates, thirteen gates were supplied along with twenty-six servomotors and thirteen pumping sets which were entirely engineered by Canadian Vickers.

These gates are another example of the precise engineering that goes into all Vickers-built water control equipment.

Upstream View of gates during erection



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pellers. The normal one is capable of delivering 5,000 g.p.h. at 50 ft. head to 15,000 g.p.h. at 17 ft. head; the alternative impeller delivers 6,000 g.p.h. at 60 ft. head to 15,000 g.p.h. at 30 ft. head. Larger and smaller pumps are in course of development, so that a range of units will ultimately be available.

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Abstracts from the World Technical Press

Blasjo Cut

A new drilling and blasting technique, called the Blasjo Cut, is now being applied at a Swedish power tunnel. It is claimed that this new technique gives a greater advance per round than the conventional V-Cut, which it has superseded. The drilling pattern of the Blasjo Cut also takes the shape of a V but, in contrast to the old V-Cut, the holes of the outer legs, instead of stopping at their point of convergence, cross it and extend beyond it for a short distance. The length of the cut-holes is 21 ft. 6 in., their inclination 3 : 1 and the charge per hole is 5½ lb. of 1 in. dynamite, detonated with short-delay caps. They are drilled 6 in. apart. The principal disadvantage of the Blasjo technique appears to be in the throw of the rock, which was found to be in the neighbourhood of 500 ft.; to counter this, part of the right-hand wall in each round was left behind and blasted simultaneously with the cut in the next round; this forced the rock to the left, and reduced the length of throw. It was also found advantageous to drill two so-called "crack-holes" in the centre of the cut, and charge them with seven 1 in. cartridges of dynamite. This also helped to suppress the throw. Holes in the Blasjo Cut are spaced 6 in. apart. Compared with the 13 ft. advance achieved by the conventional V-Cut, the Blasjo-Cut reaches an advance of 18 ft. per 7·5-hr. shift (drilling, blasting and mucking). *(Engineering News Record,* November 8, 1956, pp. 51/52, 3ff.)

Discharge Control in Low-head Hydro Plants

Advocated in the U.S.A. before World War II, the method of determining the discharge of Kaplan turbines on the basis of the difference in pressure ascertained at appropriate points of the spiral casing is now applied more and more frequently in European plants for all types of spiral-casing turbines. This method, however, has met with sharp criticisms, and its reliability has been particularly questioned in instances where the flow enters the inlet of the casing at an angle. With a view to refuting these criticisms, the author carried out a series of control tests at the Mühlrading power station in Austria, which operates from a head of 8·45 m. with four Kaplan turbines passing 75 cu. m. per sec. The plant is a normal run-of-river installation set up across the Enns River, the machine hall on the left bank being erected in prolongation of the five-bay weir abutted against the right bank. Admission to the turbines is normal. The test turbine was No. 3 unit, and admission to the neighbouring units Nos. 2 and 4 was effected in agreement with the aims of the test. During all the tests, the aggregate discharge was kept constant by the turbine farthest from the test unit, i.e. No. 1. The tests are described in detail and an analysis of the results confirms to the full the reliability of the method when applied to measuring the operating discharge of Kaplan turbines under various conditions of flow. On the other hand, the tests established that admission of the flow to the inlet at an angle has an adverse influence on the efficiency of Kaplan turbines. Extensive model tests may prove how far the position and shape of baffles in the turbine may effect its efficiency. (Dipl.-Ing. G. Schloffer, *Bulletin de l'Association Suisse des Electriciens,* Vol. 47, No. 22, October 29, 1956, p. 997, 10 pp., 12 ff.)

Harnessing the Pressy Head

This Alpine development utilises the 150 m. head available between the Giffre and the Arve, two mountain torrents flowing practically in a parallel direction and straight across the Chatillon Pass only three kilometres apart, the former eventually falling into the latter. The headworks on the Giffre comprise the three-bay weir, equipped with tainter gates 12 m. in width by 4·5 m. in height, the intake and sand trap on the left bank, and on the right bank a balancing reservoir closed by two dykes set up at an angle of 120°, the downstream dyke forming almost a prolongation of the weir, and the upstream dyke separating the reservoir from the Giffre. The power tunnel, 1,850 m. long, 3 m. in diameter, runs straight from the intake to the surge chamber at a gradient of 5·4 mm. per metre at the invert; its cross-section is not quite circular, the invert being only slightly curved to make inspection rounds and other traffic easier. The most interesting feature of this scheme is undoubtedly the surge chamber, which combines all the characteristics of the expansion chamber, restricted-orifice and differential types and thus ensures instantaneously the damping of all half-period oscillations better than a diaphragm and without causing any depression. Broadly described, the surge chamber consists of a vertical shaft divided by a wall provided with orifices into two compartments, of which the downstream one acts as a riser, and the upstream connects with a 40 m. long horizontal chamber slightly tapering towards its end. A 25 m. long chamber, with a 3% slope, leads from the power tunnel to the bottom of the upstream compartment of the vertical shaft, which, in its turn, connects at the top with an overflow chamber. Viewed in vertical cross section, the whole structure presents

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roughly the picture of a two-prong fork laid on edge, the prongs being directed downstream and the handle, upstream, and prongs and handle being connected by the vertical shaft. The orifices in the separating wall of the shaft ensure the communication between handle and prongs, that is to say between the horizontal chamber on the one hand and the overflow chamber and the chamber connecting with the power tunnel on the other hand. The power house shelters two 13,750 kW generating sets driven by vertical Francis turbines operating from a head of 143·5 m. The article ends with a detailed survey of the construction methods applied to meet the topographical and geological conditions encountered. (L. Pousse, director of EDF Alpes II Region, and P. Courdouan, head of EDF Development, *La Technique Moderne, Construction*. Vol. XI, No. 11, November 1956, p. 387, 7 pp., 11 ff.)

Orb Valley Development

The outstanding feature of this dual-purpose project is that it will divert from the Atlantic to the Mediterranean watershed in a dry year 173 million cu. m. of water, which, after producing 238 million kWh, will ensure the irrigation of no less than 15,000 hectares (37,066 acres) of farming land in the lower Orb Valley upstream and downstream of Béziers and between the Orb Valley and the Aude River to the west. The Orb is a typical Mediterranean river with a rate of flow which may fluctuate between 500 litres per sec. at its lowest level and 3,500 cu. m. per sec. at periods of violent floods such as last recorded on December 6, 1953. It is obvious that its minimum flow is largely inadequate for irrigation purposes during the dry season. Its main tributary, the Jaur, flows from west to east in a direction roughly parallel to the Tarn tribuary, the Agout, which runs from east to west, Jaur and Agout being separated by the Espinouse massif which actually forms the limit between the Atlantic and Mediterranean watersheds. Annual average precipitation in the Agout valley is about twice as much as in the Jaur catchment, whereas the average altitudes of the two rivers on their lower course are 750 and 140 m. respectively. These two facts tell highly in favour of the EDF project, which will utilise the difference in level by diverting the water of the upper Agout valley to the underground power house to be set up at Montahut, downstream of Olargues in the Jaur valley. At Laouzas, a dam will create a reservoir of 40 million cu. m., fed by the Vèbre, which flows from east to west into the Agout, and three of its tributaries. On its way from the reservoir, the power tunnel will collect near Fraine waters from the Agout itself, and then convey the whole of the diverted waters to the Montahut plant. This plant, according to the terms of the concession now under consideration, will have the following main characteristics: Head, 625 m.; discharge at full capacity, 14 cu. m. per sec.; aggregate discharge passing the turbines in a dry year, 173 million cu. m.; capacity, 67,000 kW; yearly production, 231 million kWh. The discharge from the Montahut turbines will double the volume of flow downstream of its confluence with the Jaur in a dry year. Montahut will operate at peak periods, especially from November to May, that is to say during the months when, except April and May, no irrigation water is required. The main problem consists therefore in accumulating, while the power station is in operation, the largest possible volume of water in order to release it during the irrigation season. To meet irrigation requirements fully, the setting up of a reservoir of 85 million cu. m. is contemplated on the Rieuberlou, a right-bank tributary of the Orb downstream of Roquebrun; this reservoir would operate independently of the Montahut plant. (Ph. Deymié, Ingénieur en Chef des Ponts et Chaussées, *Proceedings of Société Hydrotechnique de France*, Vol. II, 1956, p. 165, 3 pp., 2 ff., and *La Houille Blanche*, Vol. 11, No. B., September 1956, p. 523.)

The Montorio Hydro Plant

A detailed description is given of this plant which constitutes the third stage of the Vomano River development, downstream of the S. Giacomo and Provvidenza plants. The backbone of this development is the Campotosto reservoir, 150 million cu. m. in useful capacity, which feeds the Provvidenza power house by means of a 1,068 m. tunnel, the tailwater flowing into the Provvidenza balancing reservoir on the Vomano River, created by a dam 52·2 m. in height, from which a pressure tunnel diverts the water to the S. Giacomo plant, the tailwater of which feeds the Piaganini balancing reservoir, 550,000 cu. m. in capacity. The Piaganini dam is a concrete arched structure with a double-curvature surface. The diversion pressure tunnel, 13·85 km. in length, runs along the right bank of the river and connects with the underground power house by means of a penstock mounted in a vertical shaft. The surge tank is of the Johnson differential type with a ring-shaped bottom expansion chamber 3,200 cu. m. in capacity. Its vertical shaft, 6·5 m. in diameter by 36 m. in height, opens out at the top in a shallow expansion basin. The machine hall, 60 m. in length by 14·5 m. in useful width, houses three 48,000 kVA vertical generating sets, consisting each of a Francis turbine and an alternator operating at 500 r.p.m., 12·5 kV and 50 c.p.s., and two 2,520 kW auxiliary sets driven by Pelton wheels. The transformer station is in a separate excavation on the left-hand side of the machine hall, and consists of three cubicles each housing a three-phase 46,000 kVA, 12·5/230 kV transformer. The article ends with a description of the construction and concreting plant. (*L'Energia Elettrica*, Vol. XXXIII, No. 5, May 1956, p. 515, 17 pp., 21 ff.)

A French Cameroons Development

This important development harnesses the Edea Falls on the lower course of the Sanaga River at a distance of no more than 50 miles from Duala, the main port of the mandated territory. Its initial construction stage comprised two 11·4 MW generating sets which were put into commission in June and August 1953 respectively, and now supply the Duala region with energy. The second stage, scheduled for completion in November 1958, comprises a 12·5 MW unit which was to start generation at the end of 1956 in co-ordination with the first two units, and six 20·8 MW sets earmarked for the needs of an aluminium smelter. The Sanaga River, which rises in the Genderu Mountains, fairly close to the border of the British territory, splits about 6 km. upstream of Edea into a maze of branches and channels, of which the "Bras Central," divided by the power channel into a right and left arm, plays the most important part in the scheme. Of less,

importance are the "Bras Mort" on the right bank and the "Bras de la Gare" which meanders along the left bank and derives its name from the vicinity of Edea railway station on its lower stretch. On this course, the river flows over falls totalling 45 m. in head and it is the farthest downstream of these falls, with a head of 20 m., which has been selected as the most advantageous site for the power plant. At this spot, just upstream of the railway viaduct and of the town of Edea, the discharge never falls below 400 cu. m. per sec. during a short low-water period, and rises to 6,500 cu. m. during the May-November flood period. A full description is given of the installations, which entailed a huge amount of civil-engineering work. At the first stage, the upstream works, restricted to concentrating the flow of power water into the "Bras Central," comprised the following main items: (1) Closure of the left arm between the "Grande Ile" and the "Ile Avancée" by a fairly low concrete overflow dam 400 m. in length, and, between the "Ile Avancée" and a neighbouring islet, by a 40 m. long riprap dam; (2) excavation of the power channel in the rock bank separating the right arm from the left arm, an operation which involved the removal of 30,000 cu. m. of rock; (3) a system of dykes between the downstream end of the power channel and the intake to the power house, consisting, on the right bank of the channel, of a rockfill structure extending downstream into a concrete dam, and on the left bank, of a 526 m. long concrete structure acting as an emergency overflow dam to meet the highest floods, and connecting at its downstream end with the spillway block by a thin dam of the multiple-arch type, 138 m. in length and no more than 9 m. in height; (4) the intake, with nine 9 m. wide openings, of which seven were kept closed by light ferro-concrete arches pending the completion of the second-stage work; (5) the power house, erected at the foot of the falls and fed by short penstocks 6 m. in diameter. The second stage now in progress includes upstream works, which, at low-water periods, will divert the whole of the river discharge to the power house, such as an extension of the first-stage dykes and a rockfill dam closing the "Bras de la Gare" at its inlets. Downstream of the overflow dam between the "Grande Ile" and the "Ile Avancée," a 120 m. long weir with movable shutters connects at the downstream tip of the latter with a concrete overflow dyke, 275 m. in length, which extends to the mainland beyond the "Bras de la Gare." The double purpose of this weir is to regulate the intake level at El.33 in the dry season and at El.35 in flood periods, and to evacuate 4,000 cu. m. per sec. of the high-flood discharge. The downstream works include the extension of the power house for the last six generating sets, and, built on to it, a two storey structure for the transformer cubicles and the cables leading to the aluminium smelter. Once completed and in full operation, the Edea Falls project will have a yearly production of 1,200 million kWh. (R.P., *Le Génie Civil*, Vol. CXXXIII, No. 3425, July 15, 1956, p. 265, 6 pp., 9 ff.)

Applying Welded Design to Water-Turbine Manufacture

This paper, read at the 70th Annual General and Professional Meeting of the Engineering Institute of Canada, Montreal, May 1956, reviews the progress of the past 30 years in the application of welded design to water turbine manufacture, with examples of the possible wide use of fabrication in almost every item of modern plant, and the advantages of this type of construction. Extensive use of electrically welded steel plate is being made in the manufacture of the main turbine and valve components for three of Canada's major hydro-electric developments—the Bersimis, Niagara/Sir Adam Beck, and St. Lawrence projects. The manufacture of the 26 major turbine units and eight straight-flow valves is being carried out by a Canadian company employing advanced techniques of welded design and production methods. (J. G. Warnock, Head of Hydraulic Department, English Electric Company of Canada Limited, *The Engineering Journal*, Vol. 39, No. 10, October 1956, p. 1,350, 11 pp., 16ff.)

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